PORTS AND TERMINAL FACILITIES

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BY

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TO MY CHILDREN

ANNE FRANCES

AND

ROY SAMUEL, JUNIOR

PREFACE TO THE SECOND EDITION

The intervening eight years, since the publication of "Ports and Terminal Facilities," have witnessed a great deepening of thought and understanding of the problems involved in the construction and operation of commercial ports. The effort to prepare a second edition that would embrace progress in construction and in thought upon this question of marine terminals has resulted in two new volumes. Those subjects that have to do primarily with the upbuilding of traffic through competitive ocean gateways, entered into a new book, "Port Development," appearing in May, 1925, second edition, 1926. This left for the old title, space for a more thorough and detailed discussion of the marine terminal facilities in the pages to follow. Although these pages contain less than fifteen per cent. of the original "Ports and Terminal Facilities," being in fact an entirely new book on the subject, the approach to the problem has remained the same from the standpoint of efficiency of operation as to service and cost. Although an engineering study, the structural engineering side is only that of a means to the accomplishment of the end of an efficient layout, that in practice will permit of economy and despatch in operation. No constructing engineer should attempt to build a marine terminal without thorough study of operating practice. Furthermore, the traffic men should consult carefully with the wizard in materials in order to accomplish a sound materialization of his ideas. The writer only recently had a practical example of this inter-relationship. He was called to look over the plans for a huge pier for a very specific purpose, being designed by very competent harbor and foundation engineers. Being less familiar with the unusual traffic conditions of this particular pier, the engineers had taken the maximum strength of materials, deck loads, and so forth, and a conventional layout frequently seen at other ports. This course would dispel any doubt as to permanency and would disarm any criticism as to layout in view of the generally accepted examples at other ports. However, the conditions of traffic being peculiar to the situation, an hour's examination showed possibilities of saving more than $100,000 in the cost of the structure and at the same time improving its usefulness under the conditions it was to meet. The new "Ports and Terminal Facilities" will attempt to discuss the problem of material equipment of ocean gateways from this point of view of low costs of maintenance and operation through proper design to the work in hand.

The author feels that this new work in concentrating thought and practice from throughout the world is many more than eight years in advance of the first book of the same title. If the new work finds the same friendly reception that was accorded the four printings of the first edition of "Ports and Terminal Facilities," the burning of midnight kilowatts will have served a useful purpose.

Every effort has been made to give footnotes and references not only in the citation of sources, but wherever other writers or engineers have worked along parallel lines. It has been my desire not to overlook anyone who has contributed in any way to thought upon the point under discussion or was helpful in the collection of basic material for the book. However, I have followed the method of putting forward my own views argumentatively, adding citations from many sources to support the point of view. If the reader takes another view of the point under discussion and disagrees with my conclusions, I am just as pleased because disagreement will indicate that thought was stimulated and out of much thought and discussion must come real progress in the design and operation of ports and terminal facilities.

ROY S. MACELWEE.

CHARLESTON, S. C.
June 1, 1926.

PREFACE TO THE FIRST EDITION

The announcement that a course was to be given at the School of Business, Columbia University, on "Ports and Terminal Facilities" brought many letters from various parts of the United States expressing the hope that the lectures would eventually be printed. As a result of this encouragement the material has been revised and presented in this volume.

The notice taken of the course indicates increasing interest in the broader economic aspects of the problem of efficient ports. Engineers, port officials, business men, and other progressive citizens are awakening to the fact that expensive harbor works alone, no matter how well constructed, do not make a port which will succeed in bringing commerce and wealth to a city. The need for better port and terminal facilities is not only a vital war measure but of continued and increasing importance in securing to the United States its place as the leading maritime power after the war.

What does make a successful port? There are complex ramifications and subtle interrelations of economic causes and effects which determine the prospects of success of a port.

It will be the effort of this volume to point out some of the factors which enter into the problem. If this discussion stimulates others to further investigation, study, and analysis of port problems the first hope for the usefulness of the book will have been realized. And if the book aids in bringing about a better understanding on the part of the general public of the importance of the subject to the nation and to the community, the second purpose will have been realized.

My own interest in ports extends back through nearly a score of years of travel and business abroad. Intensive study of the question began some six years ago while I was in charge of the Hamburg office of an American firm that built elevators and hoisting machinery. I had much to do with the authorities of the port and had occasion to view its operation at close range. Citations from this and other ports have been as general as possible to illustrate a principle but no attempt has been made to be exhaustive.

Due to a call into the national service the lectures and a large mass of material have been prepared for the printer in weeks, where months were considered too little. Thus the final presentation of the results of these years of study has been decidedly hurried. Several interesting features

of the problem, such as finance, dues and income, the combination of beauty with utility in the waterfront, port administration, legal aspects of riparian rights and other points must be reserved for discussion in a possible second volume. The discussion of these points has been omitted not because they are of less importance, but because it must be postponed like so many others until after we have won peace.

I take this opportunity to acknowledge my indebtedness to Dr. T. W. Van Metre, Asst. Professor of Transportation at Columbia University, and Mr. W. M. Brittain, Secretary of the American Steamship Association, for valuable assistance in reading the manuscript and for suggestions and encouragement.

ROY S. MACELWEE.

NEW YORK,
June 15, 1918.

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PART I

GENERAL CONSIDERATIONS TYPES OF CONSTRUCTION

PORTS AND TERMINAL FACILITIES

CHAPTER I

THE NATURE OF THE PROBLEM

"The importance of ports and terminals in national economy has been brought home to all by the collapse of international transportation under the strain of war conditions. Ships are important, but it has been obvious, even to the casual observer, that a large part of the inefficiency and congestion which has hampered the movements of food and military supplies has been at the points of transshipment from land to water carriers. The port of New York has been congested at times until an almost complete paralysis of transportation has resulted. Word has frequently come to us that at Vladivostok cases of goods vital to Russia are piled house high along the shores of the harbor.

"As a war factor, the port problem is a serious one. If there be no quick dispatch of railway cars at the marine terminals, the inland transportation system of the country will be paralyzed and we shall have no coal nor many other things. We are sore pressed for ships, but if, because of the inefficiency of the ports and the railroads at the ports here and in France, we turn the ships around only fast enough to allow a round trip every 12 weeks instead of every 6 weeks, the result is the same as if the Germans had torpedoed half of the existing meager tonnage. On the other hand, if we are able to coordinate and operate the terminal ports here and in France so as to turn the ships around quickly and make the round trip in 6 instead of 12 weeks, we have doubled the efficiency of our present merchant shipping without having built another ship. The port problem is as important a war question as the ship problem.

"Furthermore, after the war, there will be a fierce commercial struggle to capture the markets of the world. Any parasitical expense at the terminals will act as an increased cost of production of American goods, for transportation is just as much a cost of production as raw materials or labor. If we are to hold and enlarge the markets for American goods, which will mean smoking chimneys and full dinner pails for American workers, we must scale down the unnecessary costs."[1]

[1] From "Ports and Terminal Facilities," McGraw-Hill Book Company, Inc., New York, 1918.

Importance of Port Facilities in National Defense.—This introductory paragraph to the first edition of "Ports and Terminal Facilities" proved to be true. Today, 9 years later, we know well the importance of the rôle played by ports in winning the war; the great terminals built in the United States and in France at enormous costs and in feverish haste, in most cases only to have them completed after the war was over. No further proof is needed to show that adequate terminal facilities are as essential to national defense as an adequate navy and an adequate merchant marine under the American flag. These cannot be constructed in an emergency, even at enormous cost. This is true also of the emergency fleet that was finished in the greater part after the Armistice. Its value was "in being" like the British navy. Its effect was moral rather than actual. Its potential strength overawed the German government and people into quicker decision to quit.

Importance of Port Facilities in Post-war Competition.—The second statement above concerning the importance of adequate port facilities in post-war competition has been demonstrated to a degree beyond the author's most exaggerated dreams in 1917–1918. Although suffering from the world financial depression that followed the convulsions of the war, it is already evident that our foreign commerce is not going back to pre-war figures, but already greatly exceeds them. Our own population has continued to increase, demanding more goods from abroad, from crude rubber and bean oil to silks and perfumes. These purchases will be traded out in our exports. We have a fair-sized merchant marine, and the coast-to-coast traffic through the Panama Canal is growing by leaps. But, also, the competition on the high seas and in the world's markets has reached a point that requires cheese-paring cost reductions to make any profit. This means that freight rates and prices of commodities will be reduced very close to production costs and that the ultimate survivors will be those who by greater efficiency of equipment and management can reduce these costs below the marginal traders and ship operators. Post-war competition, therefore, demands every effort to reduce the various elements of costs in international transactions, and it will be shown to what a surprising extent ship operation costs are made up of port expenses, when the ship is idle and not on its way.

The Importance of Transportation, the Nation's Second Largest Industry.—The transportation industry reaches huge proportions in the employment of capital and wage earners. Of this industry as a whole, ports and terminals form an important subdivision.

Further, the investment in our national transportation system includes in the last analysis, all special facilities provided by the common carriers, for example, terminals, transit warehouses and elevators, shops and car-houses, permanent construction on roadways, on waterways (exclusive of conservancy), on port and harbor development, air transport, etc., as well as the actual operating equip-

ment of rail, ocean, roadway, trolley, waterway, and airway. We can *see* the trains, the ships and the motors. But the *hidden* costs are equally important. The reason why some of these items appear strange in the transportation balance sheet, is because we have never been in the habit of discussing our problem as a whole.[1]

The Status of the Industry Today.—Coming to specific figures, you will be surprised to find that Transportation today is our *second industry,* with an investment (on a pre-war basis) of about $50,000,000,000, next to Agriculture ($80,000,000,000), and exceeding Manufacturies ($45,000,000,000). This is twice our national debt today and fifty times our pre-war debt, representing an investment per capita of about $475 or over $1,200 per person gainfully employed in the United States. In this great transport machine, railroads of course form the backbone, but with highway transport a close second. Communications (telegraph, telephone, cable, and radio) upon which we are absolutely dependent for the transaction of business, represent $2,000,000,000 more (not including postal facilities). The revenue demand, if all these transport agencies were operated on a reasonable basis of profitable return, would probably exceed $15,000,000,000 per year, *i.e.*, over $140 per capita, or $360 per worker. The operating expenses alone may be very roughly estimated at ten to twelve billion dollars per year. Figure all this into the Nation's family budget and you will understand its importance.[1]

The Importance of Port Expenses in Ship Operation.—In operating costs of these ships the port expenses play an important part. Just how much is easily demonstrated by a few figures.[2]

In relation to the problem of the American merchant marine, and in view of the competition which it must meet, efficiency in three directions is most essential if the United States hopes to win a place among the leading sea carriers. The three may be called operation, management, and type.

As to operation, it will be useful to take the results of an actual voyage account so the relative importance of the main items may be approximately borne in mind. The following shows percentages of expense for the voyage out of a 10,000-ton ship with cargo, and home in ballast under the old pay scale; and costs of 1920 for both subsistence and stores:

Operating Expense

	Per Cent	
Wages and subsistence	17.4	
Fuel oil	48.7	
Stores (deck and engine)	3.3	
		69.4

[1] Bibbins, J. Rowland.

[2] See MacElwee and Taylor, "Wharf Management, Stevedoring and Storage," Chap. 1, D. Appleton & Company, New York, 1921.

Voyage Expense

	Per Cent	
Loading and discharging cargo	17.4	
Buying, loading, and discharging ballast	6.6	
Port charges and sundries	6.6	
		30.6
Total		100.0

Under present conditions, the cost of these items would be about 20 per cent less, making operating expenses, proper, about 66.4 per cent and fuel 44 per cent of the whole.[1]

It will be noted that the item of cost for loading and discharging cargo, 17.4 per cent, is the same as that for wages and subsistence of ship personnel, 17.4 per cent, but that "buying, loading, and discharging ballast," 6.6 per cent, and "port charges" 6.6 per cent, are expenses that may be reduced by more efficient ports. In all, 30.6 per cent are port and terminal expenses. As serious as is the handicap of higher payrolls and subsistence on American ships, there are greater sums for the pruning knife in port expenses. These figures do not include a consideration of the large savings possible by reducing the time a ship spends in port. Although discussing the need of an efficiently trained personnel in the last analysis, the same knowledge and efficiency must be shown in planning and equipping terminals as in operating them and the ships.

One must have operated ships to realize the enormous effect of this upon the expense account of a steamer, when a day's delay means the loss of hundreds or even thousands of dollars. Quick turnaround is the key of success in operation. The responsibility for readiness, loading, and discharging, and all shore provisions for expedition belong to management. But no management can accomplish a quick turnaround if the ship's operation be hampered by inefficient or insubordinate crews or officers who cause slowing down or stoppage at sea, or hold her idle in port.[2]

Admiral H. H. Rousseau gives similar figures showing the large percentage of terminal expense to the total of all ship operating and voyage accounts:

While all port charges ultimately lodge against cargo, they may be divided into charges that are primarily borne by the water carrier, by the cargo, and by the land carrier. The percentage of expenses of a vessel while in port to the total expenses of a steamship company varies considerably with different lines and depends not only on the size, speed, and type of steamships, whether passenger or cargo, but also on length of voyage. The following are the actual per-

[1] Annin, Robert Edward, "Practical United States Ship Problems, V," *The Marine Review*, September, 1921.

[2] Annin, *Ibid.*

centages of expenses of different kinds of a steamship company running out of New York, doing passenger and freight business, for the past 6 fiscal years. The vessels of this line vary in gross tonnage from 2,500 to 9,300:

	Per cent					
	1916	1917	1918	1919	1920	1921
Port charges	3.3	1.2	2.6	3.7	1.8	3.5
Stevedoring and handling	25.0	24.2	17.4	19.1	18.7	14.2
Rental of terminals	2.5	3.5	3.6	2.6	3.5	3.9
Repairs and depreciation	9.8	10.8	18.4	18.3	14.1	13.9
Fuel, water and lubrication	11.5	12.0	14.3	13.9	11.3	14.8
Feeding passengers and crew	7.9	7.3	6.5	5.6	6.6	7.1
Loss, damages, and injuries	1.8	2.2	1.1	0.9	1.5	3.5
Equipment and stores	3.9	4.7	4.8	4.2	5.2	3.5
Wages, officers, and crew	14.1	14.1	14.0	13.3	14.1	16.6
Miscellaneous	0.7	0.6	0.5	0.5	0.5	0.8
Undistributed expense	14.1	15.2	13.7	11.7	16.2	14.0
Administrative expense	5.4	4.2	3.1	2.4	3.2	4.2
Charter hire	....	....	....	3.8	3.3	
Total	100	100	100	100	100	100
Tons of freight carried	577,686	546,660	630,055	1,103,587	634,256	408,060
Number of vessels operated	8	13	11	28	20	10
Number of trips (one way)	135	141	177	221	170	147

The above figures indicate that the percentage for each item of expense in general has varied between rather narrow limits. The unit costs, however, such as cost of stevedoring per ton of freight, average operating cost per steamer day, etc., have nearly doubled since 1916.[1]

There is little hope of large reductions in the present costs of steamship or railroad transportation. These forms of transportation have already been brought to a high state of efficiency. When the terminal problem is considered, however, conditions of inefficiency and parasitical expenses which swell the total of national waste are apparent at every step. It has been estimated that the average expense of hauling a ton of freight 240 miles in the United States is 74 cents, while the expenses of handling the same ton of freight at the terminals is 75 cents.[2] It becomes evident that the greatest hope of achieving further economies in transportation in the near future lies in the reduction of terminal expenses.

[1] ROUSSEAU, H. H., Rear Admiral, U. S. N., C. E. C., "The Importance of Port Facilities in the Development of a Merchant Marine and Commerce," before the Society of Naval Architects and Marine Engineers, New York, Nov. 17, 1921.

[2] JONES, GROSVENOR, "The Ports of the United States," . . . 1916, almost double in 1923.

Another example to illustrate the amount of terminal expenses as compared with the line haul is particularly crass because, in this case, the line haul is short and the two terminal cities are large.

Package freight is moved 90 miles by rail from Philadelphia to New York. The railroad costs for 90 miles are 27 cents. The terminal expenses are nearly fourteen times the rail haul.[1]

In connection with the figures just quoted to illustrate the one-sided relation of terminal expenses to the line haul, it may be of interest to note the comparative expense of the line haul among various vehicles.

Dray on good roads	25 cents
Steam railroads	7.8 mills
Canals	3 mills
Rivers and sounds	1 mill
Great Lakes and ocean	0.5 mill[1]

[1] YOST, H. C., *Freight Handling and Terminal Engineering*, Dec. 16, 1916.

Of course, such figures are only approximate and vary with conditions, yet the contrasts are so great that the illustrative force of the comparison is valuable for our future study of the problems.

The effect of high terminal expenses and high drayage charges as compared with low costs of water transportation is visualized by the statement that goods, once loaded, may move from Havana, Cuba, to Boston, Mass., 1,320 miles, cheaper than from one pier to another in Boston.[3]

A cargo of coal, once loaded, can be moved from New York to Rio de Janeiro at less cost than to move the pile back 60 feet by ordinary methods. With unloading charges varying from 12 to 45 cents per ton, a reduction of such charges by 12 cents is equal to a decrease of 250 miles of ocean steaming.

COSTS OF MARINE TRANSPORTATION[4]

Marine commerce is that carried on in large vessels, of deep draft, in open water, over considerable distances.

Overseas trade is necessarily marine. Coastwise trade, except local traffic, is marine. Panama traffic is all marine. Great Lakes commerce is essentially marine.

[1] FROST, HARWOOD, in "American Terminal Conditions;" also DROEGE, JOHN A., "Freight Terminals and Trains," p. 273.

[2] Agricultural implements move from Chicago to New York, 900 miles, for 49.5 cents the hundred pounds, and to Buenos Aires, 5,871 nautical miles (ca. 6,460 statute miles) for $7.50 a ton or 37.5 cents the hundred pounds.

[3] These calculations were compiled by JOHN PARDEE and ALFRED H. RITTER and published by the Great Lakes-St. Lawrence Tidewater Association in 1923 in a pamphlet, *Will the Ships Come?*—a discussion of coastwise traffic between Great Lakes and Seaboard when the St. Lawrence is open.

Our account of marine transportation will confine itself to bulk cargo at sea, bulk cargo on the Lakes; mixed cargo at sea, mixed cargo on the Lakes.

Freight Costs at Sea. Bulk Cargo.—Twelve charters for ocean carriage in 1922, which are taken as representative, give the following rates, in mills per ton mile.

Coal	—1,900 to 4,800 miles	0.72, 0.71, 0.78
Grain	—4,500 to 5,200 miles	0.46, 0.49, 0.73, 0.77
Sulphur	—3,600 to 6,200 miles	0.88, 0.96
Linseed	—6,700 to 6,900 miles	0.65, 0.75

The ordinary rate on the ocean was from 0.7 to 0.9 mills per ton-mile; two charters at less than 0.5 mills may be taken as less than going rates.

For bulk cargo on the Great Lakes during the same season, the following rates, also in mills per ton mile, are quoted as representative:

Grain	—900 to 1,000 miles	0.75 to 1.23
Ore	—900 to 1,000 miles	0.84 to 0.93
Coal	—900 to 1,000 miles	0.46 to 0.5

Coal rates are relatively low because the prevailing movement is eastbound, *i.e.*, ore and grain must move down the Lakes, coal is a return cargo of the nature of distress room.

Comparing marine rates at sea with marine rates on the lakes for bulk cargoes, the lake vessel has abnormally low terminal cost but the ocean vessel makes longer voyages; the Lake vessel costs less but it is busy only 8 months in the year.

So the rates on bulk cargo, if these charters are in both cases representative, run about the same.

Freight Costs at Sea. Mixed Cargo.—Mixed cargo costs and rates are generally higher than bulk cargo. The terminal cost is higher for handling mixed cargo. Also the bulk carrier commonly negotiates for a full load in one or more parcels while the mixed cargo carrier usually sails on a schedule.

Panama traffic coastwise gives a fair basis for estimating the economy of the proposed Lakes-to-ocean route coastwise. The boats in Panama trade are vessels of 6,000 to 9,000 tons burden, drawing 20 to 25 feet of water, fully loaded. They could come up the lakes as far as Lake Erie and, by trimming fuel and water and perhaps by an accommodation of the topload, they could pass the connecting channels to the upper lakes.

We have three gages of rates and costs in Panama-Pacific transportation. First, we have the experience of a fleet plying between the North Atlantic and Pacific ports in the United States. The charges include all costs of operation, all port expense, Panama tolls, cost of traffic, administration, and other overhead, depreciation, and interest on investment, that is 6 per cent return on capital. From 1 year's experience of this fleet we have an average cost per ton-mile of 1.47 mills.

Second, we have the cost per day at sea of a typical carrier, which differs from the ton-mile cost above in that it does not include terminal expense, with the overhead for laydays, but from which the cost per voyage may be reckoned. That figure is given at $825 per day, including Panama tolls, or $725 excluding tolls.

Third, we have the schedule of rates in effect on three representative lines running from Boston, New York and Philadelphia to San Francisco and Seattle. The rates are the same from any Atlantic port to any Pacific port regardless of differences in distance from less than 6,000 to more than 7,000 miles, a spread of 1300 miles, but varying between one commodity and another from 30 to 75 cents per hundredweight.

From these last rates and distances the following earnings per ton-mile are derived:

At 30 cents—6,000 to 7,000 miles, mills per ton-mile.. 0.837 to 0.995
At 40 cents—6,000 to 7,000 miles, mills per ton-mile.. 1.11 to 1.32
At 50 cents—6,000 to 7,000 miles, mills per ton-mile.. 1.39 to 1.66
At 75 cents—6,000 to 7;000 miles, mills per ton-mile.. 2.09 to 2.49

On the Great Lakes the only cost figures we have are taken from the reports of the Great Lakes Transit Corporation filed with the Interstate Commerce Commission. When these fleets were owned by the railroads their rates were set by

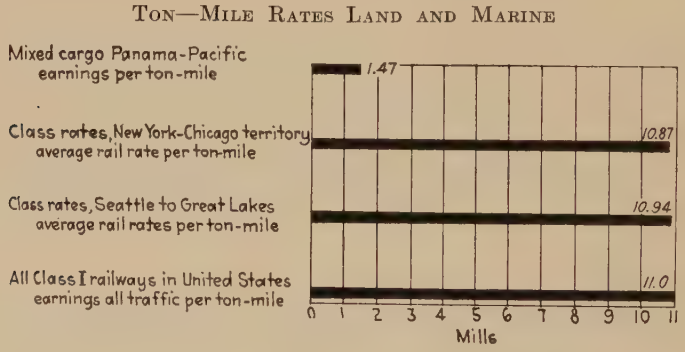

TON—MILE RATES LAND AND MARINE
Mixed cargo Panama-Pacific earnings per ton-mile
1.47
Class rates, New York-Chicago territory average rail rate per ton-mile
10.87
Class rates, Seattle to Great Lakes average rail rates per ton-mile
10.94
All Class I railways in United States earnings all traffic per ton-mile
11.0
0 1 2 3 4 5 6 7 8 9 10 11
Mills

FIG. 1.—Marine ton-mile rates.

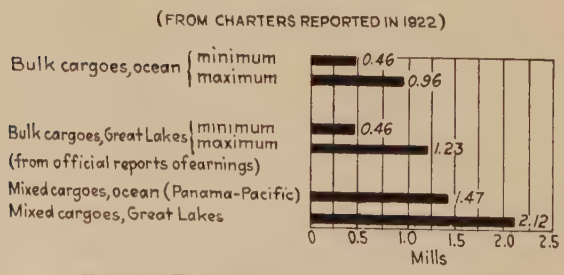


FIG. 2.—Ton-mile rates, land and marine.

rail rates and not by competition. That policy was not changed when they were turned over to other ownership in compliance with law, and the result is that operations have been conducted with much less than full loads. The ton-mile rate is therefore much higher than the rate of 1.47 mills shown by the Panama fleet.

Computed on a reasonable load factor a result is obtained of 2.12 mills per ton-mile—a figure that is not too far out of the way compared with ocean costs in view of the short lake voyage and the short lake season. Fig. 1.

Range of Competition.—According to the best figures available, there is no great difference between charter rates for *bulk* cargoes at sea and bulk cargoes on the Great Lakes.

According to the figures for *mixed* cargo, marine transportation at sea is cheaper than marine transportation on the Lakes.

Over established routes comparative economy of a given movement is shown by looking at specific rates for a specific commodity movement. In the absence of specific rates for a prospective route, we can only judge by applying customary practice to general cost figures.

We know that the ocean rate on steel products from any Atlantic port to any Pacific port is 40 cents, since adjustment (formerly 30), and the rail rate from the Atlantic seaboard to the Pacific is $1.15 (formerly $1.50). The rail rate from Pittsburgh to the nearest Atlantic port is 35 cents. At, and east of, Pittsburgh, the overland route ceases to compete with Panama.

We know that Puget Sound lumber is shipped to Montreal by sea on rates of approximately $15 per thousand less than rail rates overland, or, allowing for costs borne by the shipper, $12 net. The saving will run to $60,000 on an average cargo of 5,000,000 feet.

Such specific illustrations could be multiplied indefinitely.

Turning from specific rates to basic data, we know the ton-mile cost of *marine* transportation and the ton-mile earnings of *rail* transportation. It is not unfair to set them side by side. Cost of marine service includes operation, expense, depreciation, and interest on investment. Rates for rail service are intended to cover operation, expense, betterment, in lieu of depreciation, and interest on investment complete including dividends.

We have the range of going rates from which vessels derive earnings necessarily sufficient to cover costs, and the range of rates from which railway earnings are derived.

Vessel cost as shown by 1 year's experience of a fleet plying between Atlantic and Pacific ports was 1.47 mills per ton-mile.

Rail rates on three first-class roads between New York and Chicago in 1922 average 10.87 mills per ton-mile.

The vessel rates which produced earnings of at least 1.47 mills per ton-mile ranged from 30 to 75 cents a hundred. That is from 0.8 to 2.5 mills per ton-mile.

The rail rates, between New York and Chicago, which entered into the general average of 10.87 mills ranged from 47.5 cents sixth class, to $1.42 first class. That is from 10.4 to 31.1 mills per ton-mile.

The vessel rates are commodity rates. The same commodities in railway tariffs commonly take the same rate as classes 3 to 6 (official classification territory). Classes 1 and 2 which yield but a small fraction of railway revenues enter very little into coastwise marine traffic. Classes and commodity rates below sixth class in railway tariffs are roughly comparable to bulk cargo transportation at sea.

Now the sixth-class rate, Chicago to New York, is 47.5 cents, which is 10.4 mills per ton-mile. And the third-class rate is 94.5 cents, which is 20.7 mills per ton-mile.

It appears, therefore, that while the average ton-mile rate of 10.87 mills includes short haul traffic at local rates, obviously higher per mile than the New York-Chicago rates on the same stuff, the general merchandise movement between New York and Chicago is carried at rates from 10.4 to 20.4 mills per ton-mile. So that it is conservative to adopt 10.87 per ton-mile as the average base rate. In this way we can make up an experimental table of average base rates on mixed cargo of general merchandise and products.

As a check on the sufficiency of the assumed vessel rates, a calculation may be made on the basis of operating cost per day.

Including all overhead and operating expense of every description, the cost per day of maintaining and operating a vessel of the average type employed in Pacific-Panama service is $826.14. This includes tolls, which, in intercoastal service, will come to $100 a day, making a cost of $725 per day for vessels of this size and type on toll-free routes.

Vessel speed is 10 knots an hour or 11.5 statute miles. An average day's run is 276 miles.

From these few notes the facts will be clear that adequate port facilities, making possible quick dispatch (turnaround), low stevedoring, and other handling costs, are essential to the competitive power of the United States in foreign markets, and efficiency in ship operation to keep the American Flag on the Seas.

CHAPTER II

GENERAL CHARACTERISTICS OF A WELL-COORDINATED SEAPORT

Perhaps the best way to fix in our minds what facilities a port should offer in all its parts is to construct in outline an imaginary port. What we will discuss in brief now in order to have an outline will be taken up in detail later.

A port is the funnel for the passage of wares between lands across the seas and the interior of a country. Like the drainage basins of a river system, a port has as its hinterland an economic drainage basin for which it is the outlet. The size of the hinterland and, therefore, the importance of the port depend upon the nature of its physical connection with the hinterland. Cheapening and extending transportation will enlarge the area. There should be connection by rail and by water. Imagine a port situated on the estuary of a long, navigable river leading into a fertile country with well-developed agriculture and industry. Also suppose that various networks of railroads connect the port by land with a similar prosperous interior. What will be the demand made on such a port, and how must it be laid out in order best to serve the hinterland?

At the very beginning of the problem must be noted what may be called *the reservoir principle.* The system of transportation from an American factory to a foreign consumer is composed of many movements, each distinct, yet each part of the whole. Transportation by rail, carts, piers, ships, etc., involves a series of distinct movements, each complete in itself. These separate movements can not be entirely synchronized. The result is that one movement does not keep pace with the others. Where the joint occurs there is either lost motion or congestion. It is like the internal combustion engine which develops power every fourth count, and every second time the fly-wheel turns over. That is why there is a fly-wheel; to take up the power when it occurs and carry it over the dead centers. In a transportation system there is the same sort of intermittent motion along the routes. With the exception of belt and bucket conveyors and pipe lines there is no continuous movement, the ideal to which freight handling aspires. Therefore fly-wheels or reservoirs must be devised at the termini of each intermittent movement to take up the load and hold it until such time as it may be carried further. The smaller the number of the cylinders the larger the fly-wheel. The greater the irregularity of ships, freight trains, or canal barges entering the port, the more provision

must be made for carrying the load over the dead centers. For instance, the ore and coal stock piles at the steel works on the Great Lakes must carry over a five-month dead center of frozen navigation. Our eastern cities without such reservoirs can not exist 5 days without coal.

The two great reservoirs are the *warehouse* and the *transit shed.* A transit shed is the building on a wharf for the temporary storage of goods in transit between the ship and the railroads or warehouse. As subdivisions of these two units there are many minor points where reservoirs are necessary. One is the point of deposit of freight transferred from the hold of the ship to the wharf. Freight must not "hang" for lack of place to set it down. There are also points for loading carts, freight cars, barges, or lighters.

There is no blanket expedient, no panacea, no cure-all. Each point must be discovered in the particular system and each case solved on its own demerits.

The railroad problem in relation to port operation is very complex and at present is in a state of flux. Nevertheless, there are certain fundamental principles which must be stated.

The first is that with equal facilities for handling and with equal port charges the port with the widest choice of transportation facilities to the interior will be the greatest port. These facilities include waterways as well as railways. The larger ports of Europe are the ports at the mouths of great navigable water systems, such as Rotterdam on the outlet of the Rhine and Meuse systems, and Hamburg on the Elbe-Oder system. Antwerp is the port for the Scheldt and Belgian-French Canal systems. Inland water navigation is important to the port. Yet even in the case of the highly developed German waterways two-thirds of all the tonnage travel by rail. A port will be great if there is a large choice of connections with the interior. There is no case of waterways *versus* railways, but it is waterways *and* railways which make the port attractive to shipping. Many connecting lines act as the increase in the number of cylinders which makes a motor run smoothly.

If the port with the best prospects is the port with the most connection by rail and water with the interior, it follows that there must be equal, universal, and free movement between any pier and any railroad line. To this must be added universal connection with any warehouse, and free movement from any one part to any other part. A port must be a unit in respect to all its terminal facilities. Although it is still far from ideal, the reason that New York has grown beyond all other Atlantic ports is this universality of railroad connection. The complete harmony between every ship and every rail line is accomplished by so-called "free lighterage." Free lighterage is the lighterage service performed by the railroad as part of its service included in the freight rate, between the end of the tracks of the railroad and any part of the port of consignment,

The advantage of the coordination has been so great that the expense of lighterage and the freight-rate differentials against the port have been offset by better service, and the port has prospered.

To reiterate, port planning involves the establishment of two main reservoirs, the pier shed and the warehouse, with a completely flexible universal connection between them and all vehicles by land and water. Keeping constantly in mind these two points, reservoirs and flexibility or physical connection, what are the freight movements at a seaport necessary to connect ocean and land transportation?

Freight Movement at a Port.—An analysis of the kinds of freight involved in marine terminals will show four distinct categories:

1. General cargo:

a. Miscellaneous package freight. Various sizes and shapes of bundles from steel rods shipped naked to crated motor trucks or locomotives.

b. Standardized package freight. Many packages of a uniform size—bags of coffee, sugar, etc., crated canned goods, barrels of cement, etc., bean cake, bales of cotton or wool, hogsheads of tobacco, etc.

c. Perishables. Also in standard or uniform units—frozen carcasses, crated fruits, bananas in bunches.

2. Bulk cargo:
   a. Free flowing. Hard grains; oils in bulk; petroleum.
   b. Rough bulk. Coal, ore, gravel, limestone, kainit, phosphate rock, etc.

3. Passengers:
   a. Cabin.
   b. Steerage.

4. Highly valuable freight:
   Mail, specie, passenger's baggage.

Obviously each group requires particular accommodations. It is not always possible to handle the various groups in specially designed quarters, but the greater the degree of the segregation the more it will be possible to design special labor-saving machinery and reduce the cost of handling.

Bearing in mind the four classes of freight, the movements in a correctly planned port may be as follows:

I. From the *pier* the goods may move:

   1. To *railway car* to be switched to the
      a. Trunk line for the interior, if in car load lots (c. l.).
      b. Transfer yard for consolidation if less than car load lots (l. c. l.).
      c. Warehouse with spur siding for storage.
      d. Industrial plant with spur siding for consumption.

   2. Or to *dray* for delivery to
      a. Local consignee not otherwise reached.
      b. Warehouse not otherwise reached.

3. Or across the pier—if it is a narrow transfer pier as at New York—to be *lightered* to

a. Warehouses with waterside delivery (lighter canal).

b. Industrial plants, with waterside delivery.

Railroad freight should not be lightered except at ports where the belt line railway is an impossibility.

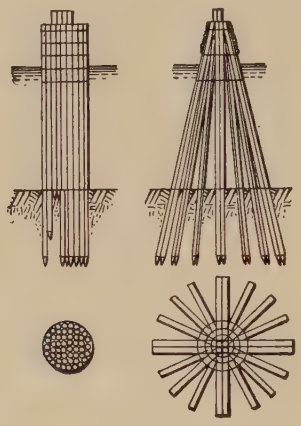


FIG. 3.—Mooring posts—dolphins, dollies, Duke d'Albe—for mooring ships in stream.

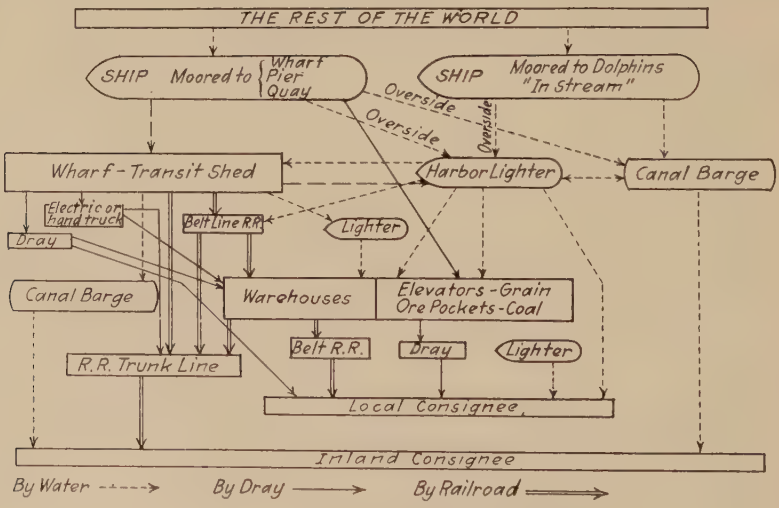


FIG. 4.—Port movement of inbound freight.

II. *Overside* at the pier the cargo may be loaded directly onto lighters

a. For movement to warehouses with waterside delivery.

b. To industrial plants with waterside delivery.

c. To barge canal terminals in broken lots, otherwise cargo overside may be loaded directly to canal barges.

III. *Overside in Stream.* Cargo ships berthed *in stream at mooring posts* will discharge overside. Fig. 3.

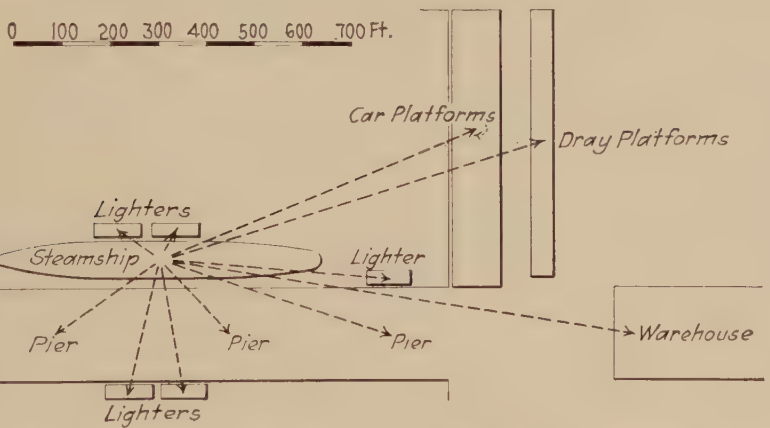
a. Into barges for the interior.

b. Into lighters and scows for local consignees having waterside delivery.

c. Minority cargo (in the case of a ship carrying its main cargo in bulk and a small portion as package freight) to: (1) warehouse; (2) railroad freight stations; (3) industries.

Cargo ships carrying largely bulk cargo and some parcel freight, but enjoying the free berthage afforded by the mooring posts for bulk cargo, will prefer to lighter the small proportion of package freight rather than pay wharfage on the entire ship.

In order to visualize the freedom of movement which a well-organized port should offer the diagram in Fig. 4 may be helpful. It will be seen that the various vessels and vehicles, in order of importance, are: belt railway car, harbor lighter, and river barge. The dray should never be called into use except when there is no available switching or lightering service. Through railroad freight should always be switched. The diagram illustrates what is meant by free and universal flexibility of movement.



(Calvin Tomkins, Commissioner of Docks, February, 1912. City of New York Department of Docks and Ferries.)

FIG. 5.— Diagram showing freight movement in a mechanically equipped marine terminal.

The movement at a New York pier with a bulkhead warehouse and bulkhead rails or car-floats, not a usual, but a desirable condition, was shown by the late Hon. Calvin Tomkins in Fig. 5.

2. THE PLACE OF IMPROVED TERMINAL FACILITIES AMONG THE BASIC PRINCIPLES BEHIND PORT DEVELOPMENT SUCCESS

To this point in this chapter the discussion has centered about port facilities alone. These facilities are essential but in themselves will not build commerce. In interest of a clearer view of the discussion in "Port Development" and in the chapters to follow here seven principles or fundamentals may be summarized:

Seven Fundamental Principles.—1. There should be car and water connection with a prosperous interior.

2. There should be *rates* to these interior points equal to, or better than, competing ports.

3. There should be *an equal flat rate switching* or lighterage system between all carriers entering the port and every wharf in the port.

4. There must be facilities at the port designed to handle special bulk and general cargo with economy and speed.

5. *Balanced Cargoes* (*a*).—Cargoes are attractive to ships if the load factor of the port is balanced, that is, if ships can get a cargo into the port and another cargo out. (*b*). A port is attractive if cargoes are balanced with regard to stowage factors, in order that a ship may "be loaded full and down," neither all steel rails nor all cotton.

6. *Physical advantages*, natural or acquired, are good talking points, but many of the great ports of the world have had no natural advantages, facilities having been created artificially through shrewd financing and engineering skill. However, a port, whether natural or artificial, must provide: (*a*) adequate water; (*b*) safety as a harbor; (*c*) ease of access is more important than proximity to the sea; (*d*) aids to navigation such as lights, buoys, radio finding, submarine signals; (*e*) it should be comparatively free from fog and ice; (*f*) the port should also be a healthful one as quarantines are expensive and vexatious delays.

7. The seventh, last, and one great important point is that cargoes must be provided. *A ship will go anywhere it can float in order to get paying cargoes.* These cargoes must be furnished by the merchants who get the business. It is true that frequent and diversified sailings stimulate shipments, but the growth of any port depends first, last, and always upon the ability of the merchants of the port to handle business through the port. In that case, it is easy to dig a harbor out of the mud and equip it with machinery to handle the ships that visit the port. Once started, the reflex actions of cargo attracting ships and steamship services attracting and stimulating business will grow like a snowball.

The place of port facilities is obvious. Quick dispatch at low cost depends upon adequate terminals with all the many details embraced in the term "adequate."

Terminal Design to Obviate "Bottle Necks."—There are points in all inter- and intraterminal movements where congestion occurs due to the failure of the traffic to move on at the proper speed. Such a point is referred to as "the neck of the bottle." The problem in terminal layouts is to analyze what causes bottle necks and by design and by operating management remove the cause of the stricture. For example, when supplies began moving in great convoys to France there were no terminals to receive the cargoes. Wharves were built with batteries of great cranes that discharged the ships, but the supplies could not move away

from the wharf fast enough because there were not enough railroad tracks. These were supplied, but there were not enough cars, then there were not enough locomotives. Finally the wharves could be cleared as fast as the ships were discharged. But the bottle neck had moved inland where warehouses were built in feverish haste to store the supplies and release the cars, to go back and relieve the wharves, to relieve the cranes that relieved the ships. It was some time before all the bottle necks had been widened out to offer a balanced accommodation of a peak load of traffic all along the road the war supplies had to travel. This was accomplished about the time the battle front activities reached their maximum. It would have been a great war if it had not stopped. Terminal engineers paraphrase *cherchez la femme* to "find the bottle neck."

PORT TERMINAL TERMINOLOGY

What is a Port?—The question may be answered in the Yankee manner by asking, What is a harbor? A harbor is a sheltered body of water of sufficient depth to enable a ship to find shelter in it from the storms of the high seas. *If to a harbor or haven we add terminal facilities we have a port.*[1] The terms are used loosely.

Harbour is taken from the old English *hereberge*, meaning protection or shelter. The French *auberge*, an inn, is derived through hebeger. In German, *cherberge* an inn, is thus the same word; a place of refuge, of shelter. Harbors may be divided into three distinct groups, namely—lagoon harbors, jetty harbors, and sea-coast harbors, protected by breakwaters, including refuge, naval and commercial harbors.

A port is a harbor plus terminal facilities.

Dock in Marine and River Engineering.—Vessels require to lie afloat alongside quays provided with suitable appliances in sheltered sites in order to discharge and take in cargoes conveniently and expeditiously; and a basin constructed for this purpose, surrounded by quay walls, is known as a dock. The term is specially applied to basins adjoining tidal rivers, or close to the sea coast, in which the water is maintained at a fairly uniform level by gates, which are closed when the tide begins to fall.

A wharf is a place for loading or unloading ships, or vessels, particularly a platform of timber, stone, or other material along the shore of a harbor or along the bank of a navigable river against which vessels may lie and discharge their cargo or be loaded. The cognate word in Dutch *werf* and in German *Werft* meant a wharf or a shipbuilder's yard; in Danish, *vaerft* meant dock yard.[2]

The owner or occupier of a wharf is styled a "*wharfinger*," properly "wharfager."

[1] See glossary of port terms, published by the American Association of Port Authorities, New Orleans, La.

[2] *Encyclopædia Britannica.*

A *stevedore* is a person who contracts to load or discharge a ship.

A *longshoreman* is a laborer employed by a stevedore to carry out this contract.

Wharf is the general term for a landing place for vessels and cargoes.

A pier is a wharf structure that projects into a stream or fairway with water on both sides.

Slips are the open water spaces or docks between adjacent piers.

Quays are wharves parallel with the basin or "harbor" with water on one side.

It has not always been possible to adhere to these distinctions, since at a number of ports the terms "wharf" or "dock" have long been commonly used in the designation of terminals. Thus at Boston some of the piers along the Atlantic Avenue waterfront have been known for scores of years as India Wharf, Lewis Wharf, "T" wharf, etc., and at certain ports on the Great Lakes the iron-ore and coal terminals have been generally and for years referred to as "ore-docks." Words that adequately describe the form of construction have not been used in such cases.

In a discussion of port administration in the United States it is desirable that a distinction be made between the harbor and the port. The harbor may be defined as consisting of the waterways and channels as far in as the pierhead lines, and the port is including everything on the landward side of those lines, that is, the piers, slips, wharves, sheds, tracks, handling equipment, etc. This distinction, while technical and somewhat novel, tends to mark off distinctly the limits of the jurisdiction of the Federal government and the jurisdiction of the state and municipal authorities. It cannot be strictly observed in the present work because of the strength of prevailing local usage, which fails to distinguish between harbor and port.

Quay System.—Owing to a considerable confusion of terms, it may be well to add that the definition for quays given above is applied to the terminal equipment around any dock, basin, or slip that shows the characteristic of complete parallelity of all elements. It is not confined to the line of a natural shore, but is usually found in those artificial dredged basins characteristic of most European ports situated on rivers and forced to expand by digging into the land. The elements of the quay system, naming them from the water, are: (1) string piece or apron or open space along the quay wall with cranes or other transfer machinery; (2) railroad siding; (3) transit shed; (4) marginal street to admit tracks and drays; (5) a warehouse—but not always—with rail and truck connections. It will be noted that all elements are parallel with the ship and with one another. Any arrangement of a waterfront exhibiting these characteristics belongs to the quay system of layout.

Quay pier, is any port land area between two harbor basins carrying two quay systems back to back, approximately parallel with each other.

This has been the name generally given by John Meigs, by the author, and by a few others, to those large filled piers of great length and width carrying two complete quay arrangements of facilities. English harbor engineers frequently call this a jetty; Italian engineers, a mole. These terms and the system of the port layout which they describe, are necessary of careful definition and discussion because the quay system is new in the United States, but increasing in favor in all recent construction.

Port development may be defined as embracing all those human activities whose purpose is the increase in the traffic and facilities of a port. This problem is covered in another book by the author bearing that title. Terminal facilities are a part of port development, but capable of more detached and separate treatment.

What is a Terminal?—A term*inal* is the end of a movement in transportation. It may be either end. It may be for passengers or for goods. A term*inus* is the end of a line. They are not the same although the termini of a railroad or of a steamship line are the most important terminals of the line. Add to this the consideration that in most cases of oversea transportation, the passengers or freight must pass from the terminus of the land carrier to that of the ocean carrier, or *vice versa*, and the importance of the problem of connecting the two systems becomes evident. A port is a harbor plus facilities to expedite this movement.

What Do We Mean by Terminal Facilities?—*Terminal facilities are all those arrangements, mechanical and engineering, which make easy the transference of passengers and goods at either end of any stage of the journey.* It is true that a large part of the problem is mechanical and belongs to the sphere of the engineer. There are all sorts of power-driven machinery for handling freight. The engineer is an important factor in constructing a terminal. However, cranes alone will not make a port and electrical trucks will not make a freight terminal, although mechanical equipment is indispensable.

The port or the freight terminals of a city must be considered as a unit, with all its parts designed and laid out in relation to the whole city and harbor, coordinated into one instrument. Terminal facilities therefore comprise all the most ingenious mechanical, engineering, and architectural construction united into one definite policy and plan. We must, perforce, discuss minutely many details, many component units, but we must never lose sight of the ultimate function of the unit under consideration in the operation of the whole.

Port Facilities are a Broad Problem.—Terminal planning is a work for both engineers and economists. There has been real cooperation between the two sciences recently. There has been a tendency to build wonderful piers as engineering structures which do not link up with the rest of the system, and there has been port planning which would not stand up because of the engineering deficiencies. The day has arrived

when there is a new profession of engineer-economist to solve involved transportation problems, just as the patent attorney must be an engineer. The building of efficient ports will require the best engineering talent that the land can produce. Our achievements on the Great Lakes in bulk cargo loading, transport, and unloading have far surpassed any like achievement abroad. Our American engineers are more than equal to the task if given the right conditions. The failure of our American ports in this crisis is not due to the engineers. The forces at fault are far less conspicuous and far more elusive. The failure of American ports at the crucial time was due to the peculiar conditions of American railway history, in particular to the competition of rival lines at the terminals. A new era in American railroading is dawning and it is for this new era that we must plan. Planning and execution will require engineering- economists.

There is no short cut to the perfect port. Engineering-economist and administrator must cooperate. Just as in the design of an aeroplane, the way to make the machine light is to reduce the weight a little here and a little there. No one thing will do it. One little saving added to another little saving will in the end make a large difference in the weight of the motor, and so also in the cost of putting American products on the markets of the world.

In port design there are two mistakes that are easy to make. One is to perpetuate our own past errors and bad practices as a matter of habit or familiarity. The other is to copy bad practices from abroad along with the good by Chinese-copying successful foreign ports, under the delusion that *eo ipso* they will function when transplanted to America. We need to analyze our own requirements in the light of far-reaching knowledge of port conditions at home and abroad.

Not only engineers, economists, and administrators, but also the general public should be interested. The general public, which means the voters in a representative government, the sovereign people whose will rules, has considerable knowledge of railroad problems, and is rapidly learning much about shipping problems, but it has very little interest in, or knowledge of, the vital link between the two, the port. The time is opportune for a more general knowledge of the subject of port facilities. The war should have demonstrated that ports and terminals are the concern of every citizen of our great Republic.

CHAPTER III

WHARF DESIGN—QUAY-PIERS AND OTHER TYPES

The wharf, pier or quay, is an artificial structure in water deep enough to permit vessels to tie up against it and load or discharge cargo. The function of this structure, which may be any one of the three types mentioned in Chap. II, is to afford direct connection between the water carrier and the land with its many vehicles. The wharf is the point of contact between water and land carriers.

The equipment of the landing stage consists of many elements. There may be cranes, cargo masts, conveyors, or other mechanical means of transferring the cargo from ships' hold to wharf or there may be no equipment whatsoever, the tackle of the ship being the main reliance. Then there may be various means of moving the freight along the pier and away from the pier to the consignees. This may be accomplished by means of hand trucks, electric trucks, telphers, drays, railroad cars, and other devices. The most important equipment, however, is the transit shed to protect cargo held temporarily on the wharf in transit between ship and shore. The nature, function, and arrangement of these various elements of the well-equipped wharf must be studied in detail and in their relation one to the other.

The wharf or pier in itself is an engineering problem. Before considering the economics of wharf design there must be some understanding of the technical difficulties which the constructing engineers who carry out the design will probably encounter.

The wharf structures surrounding docks or tidal basins in European ports are usually of filled structure while the wharves along levees of rivers in this country are at least partly of pile construction. It is evident that the strips of filled and walled land between two basins or docks in many European ports are nothing more than gigantic filled piers several thousand feet long and several hundred feet wide. This fact, that the large excavated basins are only the intervals between large piers of solid construction brings out the first axiom of wharf construction.

The longer the pier the wider it must be and the wider the water basin or slip separating it from the next pier.

The reason for the narrow pier is historical. The city or state had title to land under water at the extension of the streets, and the pier was therefore no wider than the streets of which it was an extension.

The piers were large enough for the ships at the time they were built. This is no reason for retaining the narrow pier system for the modern large ships.

When piers and when quays and when marginal wharves are to be used is a matter of circumstances.

If a river is narrow, only marginal wharves or quays can be used. When the capacity of the wharves has been reached, there is nothing left to do but dig into the shore. If the land is low and soft, there should be no difficulty in this. Practice in the past points to the preference for the long, wide basins with solid-fill quays. If the land out of which a basin is to be dug is low, the spoil from the excavations will be most cheaply disposed of as fillings.

GENERAL TYPES OF WHARF LAYOUT

There are several distinct systems of general layout of port terminals and as many schools of adherents or advocates.

1. Pier and Slip System, as at New York.

2*a*. Quay and Basin System, as at Hamburg, Rotterdam, English and French ports with wet docks.

b. Marginal Quay System, as in the Scheldt Bank at Antwerp, or Rio de Janeiro.

3. Double Pier and Slip System, as at Philadelphia, Norfolk, Charleston.

4. Quay-pier System, as at Seattle, Kobe, Parr Terminal project, Quartermaster Base Philadelphia.

5. Trunk and Branch System, Tacoma, Washington; Central of New Jersey Railroad, Jersey City.

6. Square and Slip System, as at Savannah, and Francis Lee Stuart's project for Baltimore.

7. "Oyster Fork" Quay Piers as proposed for India Basin, San Francisco, a Baltimore project, a Jamaica Bay project.

A rather detailed discussion of the traffic advantages of these various systems is essential to further investigation of port terminals.

TYPE 1. THE PIER AND SLIP SYSTEM

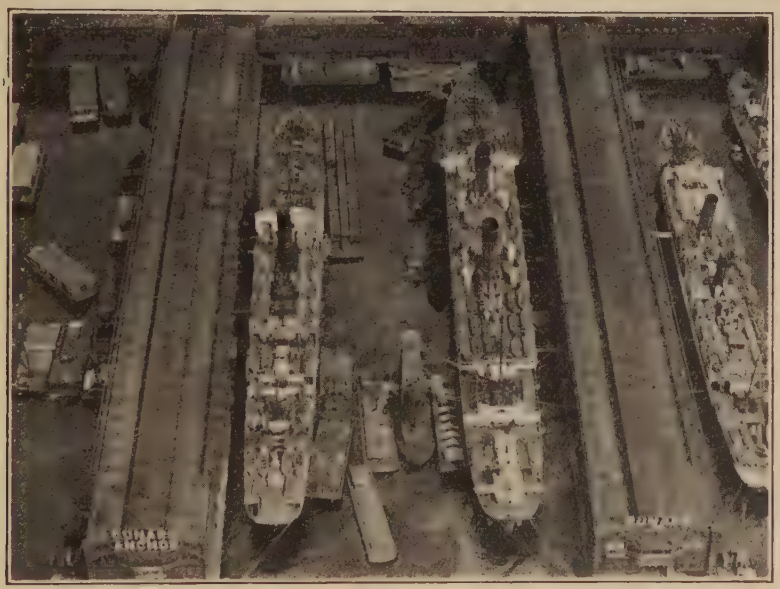
If a river is wide enough the pier construction, as we know it in New York, is the most economical waterfront, measured alone in linear feet of berthing space (Fig. 6).

For example, a marginal warf 2,000 feet long will accommodate only four 500-foot ships, but on such a property may be built five piers, each 1,000 feet long and 150 feet wide with slips 250 feet wide between them, which provide berthing space for twenty ships.[1]

[1] Greene, *Wharves and Piers.*

This is true enough. The danger lies in looking at this one point of waterfront economy to the exclusion of other features, such as the necessary equipment and the entire problem of economy in time and labor in freight handling. These points must be balanced against one another.

Advantages of the Pier System.—The first advantage of the pier system (60 by 600 feet to 120 by 1,200 feet) is the comparatively inexpensive structure for small-scale development. A small ship line or railroad, a sugar refinery, or a warehouse company acquires a few hundred feet of shore line and builds a private pier that will take care of two or three



(*Courtesy, Air Service, U. S. A.*)

FIG. 6.—Piers of Cunard and Anchor Lines, New York. The modern great linear requires the 1,000-foot pier. Note (1) the ships are "breasted off" from the pier to admit bunkering barges and to give more operating room. (2) This narrows the slip waters until the floating grain elevator and two grain barges (front center) entirely block the slip. In the slip, discharging into forward hatches of left-hand liner, is a car-float, presumably with refrigerator products. The one flat car is "the neck of the bottle" through which the contents of nine cars must find its way *via.* the narrow center platform. Yet this is a modern layout, more commodious than many.

vessels. The wharfage needs are satisfied. For a small development a pier represents a smaller capital investment than a complete quay equipment. In a large harbor unit project this is not necessarily true; on the contrary. With a rocky shore of valuable urban land, such as the Manhattan or the old Philadelphia waterfront, there is no choice but to build piers out as far as the army engineers permit, without unduly obstructing navigation. If the piers cannot be long, they need not be more than of a certain moderate width. The width, as a function of the

length, forms an important problem of pier design. Railroads, drayways, and warehouses are located along the shore line more or less at right angles.

It is a mistake to construct piers at right angles to the stream or current as is usual at New York, Philadelphia, and elsewhere. Piers should be inclined downstream at an angle of perhaps 45 to 60 degrees to the bulkhead line to permit easy docking of large vessels when the current is running strong. It takes a large vessel as long as 2 hours with the help of 10 tugs to dock against ebb tide at Hudson River piers.

A typical New York pier may be taken to be 1,000 feet long by 100 feet wide. It is, of course, well known that few New York piers are as commodious as this, many being only 50 to 80 feet in width even when of considerably greater length. A discussion of this type of pier from several angles is essential to the argument.

At New York, from which the American pier system emanates, there are several local conditions that led to this particular development in the beginning:

1. The shore line is rocky and no changes could be made in its contour by dredging.

2. No land could be spared from Manhattan Island for the construction of deeper slips or basins, as was the case in the early development of Havre, Rotterdam, Antwerp, London, and other ports (not Hamburg) more than a century ago.

3. The river is of great width, making it possible to build out into it without materially reducing the fairway.

4. The development of the port was accelerated by the Erie Canal, whose canal boats could proceed to any pier along the North River (Hudson) and discharge across a narrow pier to the ocean ship.

5. When the railroads became a factor their tracks terminated on the New Jersey mainland across the river from the island waterfront of Manhattan. Therefore, to compete with the canal it was necessary to lighter "free" the merchandise from the rail ends to the ship or to a pier across which the merchandise was loaded into ships. New York piers were not reservoirs for rail or dray freight awaiting loading, but a transfer bridge across which freight held on lighters or canal boats was put into the ships. More than half the freight is now handled directly from lighter without use of the pier deck.

6. The ships of the days when General McClellan laid out the waterfront, about half a century ago, were very small compared with modern cargo carriers.

For transfer of lighter freight to vessels, the narrow pier has the same advantage that the narrow streets of old Havana afford for the weary pedestrian; it is a short walk in the hot sun. Modern traffic, however, is greatly hindered by these inherited restrictions.

The bad results to traffic occasioned by the peculiar conditions at New York and the adherence to custom in pier design even for the new piers may be analyzed with profit. Some of these consequences are:

a. General congestion, because the pier deck cannot hold the cargo. Much is held on lighters where it may be exposed to the weather. The lighters occupy deep-water space that could be utilized either for more commodious piers or for ship berths.

b. Confusion in making delivery of discharged cargo. The complete sorting of discharged cargo according to marks and consignees is absolutely essential if delivery is to be made promptly. A merchant attempting to take delivery of a consignment from a congested wharf finds the goods scattered about, often buried under other freight piled high on the pier. His truckmen must wait long hours at great expense, obstructing traffic, and then depart with only a partial delivery. Further trips are necessary to complete this short delivery. In the meantime the 48-hour, free-time period may have elapsed, the scattered packages being sent to general stores, with expenses charged to the merchandise. This means further delay and expense.

c. Congestion of trucks at the pier entrance and along the marginal street is due to conditions on the pier caused by insufficient deck spaces, and by only one bottle neck entrance.

d. Lighterage freight delivered to the ship has a flexibility of movement, particularly when transferred overside from the waterside of the ship. In taking delivery of discharged cargo, however, marks are frequently mixed, in spite of great care. Short shipments, delays, and broken lots are the result. Also, the ship is delayed in discharging when hold sorting is necessary. A ship can discharge much more rapidly if marks are ignored aboard ship and the sorting is done on a pier deck. Of course, all these remarks refer to miscellaneous shipments for many consignees. The frequency of solid cargoes has become constantly less with the increase in size of ships and the predominance of liner services.

Pier System Wasteful of Berthage Space.—The pier system in operation is wasteful of berthage space despite the fact of the greater lineal measurement. During the recent war and post-war years of congestion at New York, when the bay was full of ships waiting for accommodation at berths, a trip along the waterfront would disclose slip after slip with empty berths. The berths were empty, but were not available for working a ship for several very good reasons. In the first place a small line operating a weekly or bi-monthly service with four to six steamers will average only one ship at the pier at a time. Yet it is obviously essential that this line have complete control over all of this one pier. It is difficult to dispatch the steamer promptly unless most of the cargo is assembled in advance and arranged on the pier ready for quick transfer and stowing. In order to arrange cargo in advance and to safeguard it while on the pier,

the necessary space must be set aside before the vessel berths, and it is impossible to assign another ship to the berth in the meantime. This condition may be overcome partially by proper supporting warehouses.

Also, on a long, narrow pier, a vessel being worked at the inshore end will effectively interfere with cargo moving along the pier to the outshore

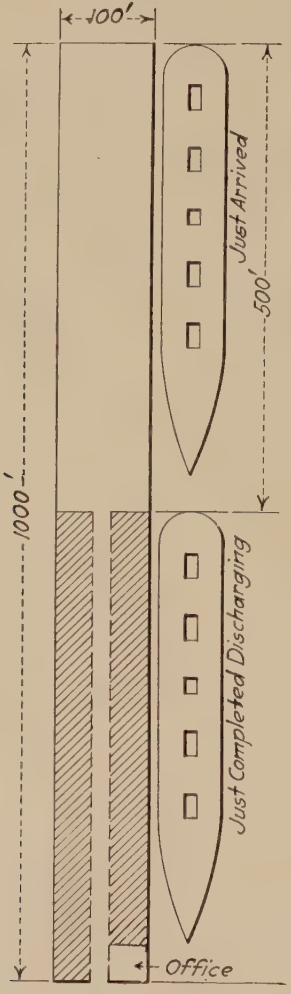


FIG. 7.—Inshore ship being worked, shuts off outer end of the pier.

berth. Of course, lighter freight will not be obstructed, but all local delivery freight from the outshore berth must find its way over, under, around, and through the cargo on the pier from the ship at the inshore berth.

A line operating a fleet of ships on regular sailings would not find it profitable to permit outside vessels to berth at the pier. The losses that

might be incurred would certainly far outweigh any gain of $200 a day berthage (dockage) that might be collected. Therefore, with a harbor full of ships waiting for berths, many piers will be found without any ships in berth—or perhaps only one or two out of a possible four.

Figure 7 illustrates this situation. The pier is fairly typical, being wider than the average. The Hoboken piers of the North German Lloyd and Hamburg-American lines were only 75 to 85 feet, while the Chelsea piers are 1,000 by 125 feet. It must be remembered that passenger steamers of the racing type do not carry a large amount of freight. Nevertheless, the pier may be taken as typical. This gives 100,000 square feet of deck space on each deck. The linear berthage front would be 2,000 feet, theoretically berthing four 500-foot vessels, each of 10,000 deadweight tons. The pier in practice could not possibly work four such vessels with dispatch or economy. It has been calculated that for short-time storage it is not economical to pile above 5 feet high. If a perfect average stowage factor of 1 is assumed for the ship and tiering 5 feet high, 10 square feet per ton of cargo would be required, leaving 25 per cent of floor space for aisles. (A "measurement ton" of 40 cubic feet would occupy 10 square feet if piled 4 feet high, with no space for aisles, and it is obvious that if the pile were 1 foot higher 20 per cent of the space would be left for aisles.) Then the entire pier and both decks would accommodate all the cargo of only one vessel at a time. It is safe to assume that no more than half of the total cargo would be on the pier at one time, as the other half would be divided between ship's hold, lighters, and shipper. Aside from the inconvenience caused by the inshore berth blocking the outshore berth, a pier 1,000 by 100 feet can accommodate two 500-foot vessels, each of 10,000 deadweight tons.

The Hon. Murray Hulbert in 1920, while Commissioner of Docks of New York City, made the following statement of pier conditions and pleaded for their modernization:

> In considering the improvement of the North River we must bear in mind these facts:
>
> At present there are thirty-four piers on the North River between Vesey Street and Perry Street.
>
> These piers were built substantially in accordance with the plan laid out by Maj. Gen. George B. McClellan (who was employed by the Dock Board as Chief Engineer at a salary of $20,000 per annum), and approved in 1871.
>
> Of these thirty-four piers:
>
> Only one pier is 125 feet wide (the old American Line Pier at Fulton Street).
>
> Three piers are 100 feet wide.
>
> One pier is 90 feet wide.
>
> Five piers are 80 feet wide.
>
> Nine piers are 75 feet wide.
>
> Two piers are 70 feet wide.
>
> One pier is 65 feet wide.

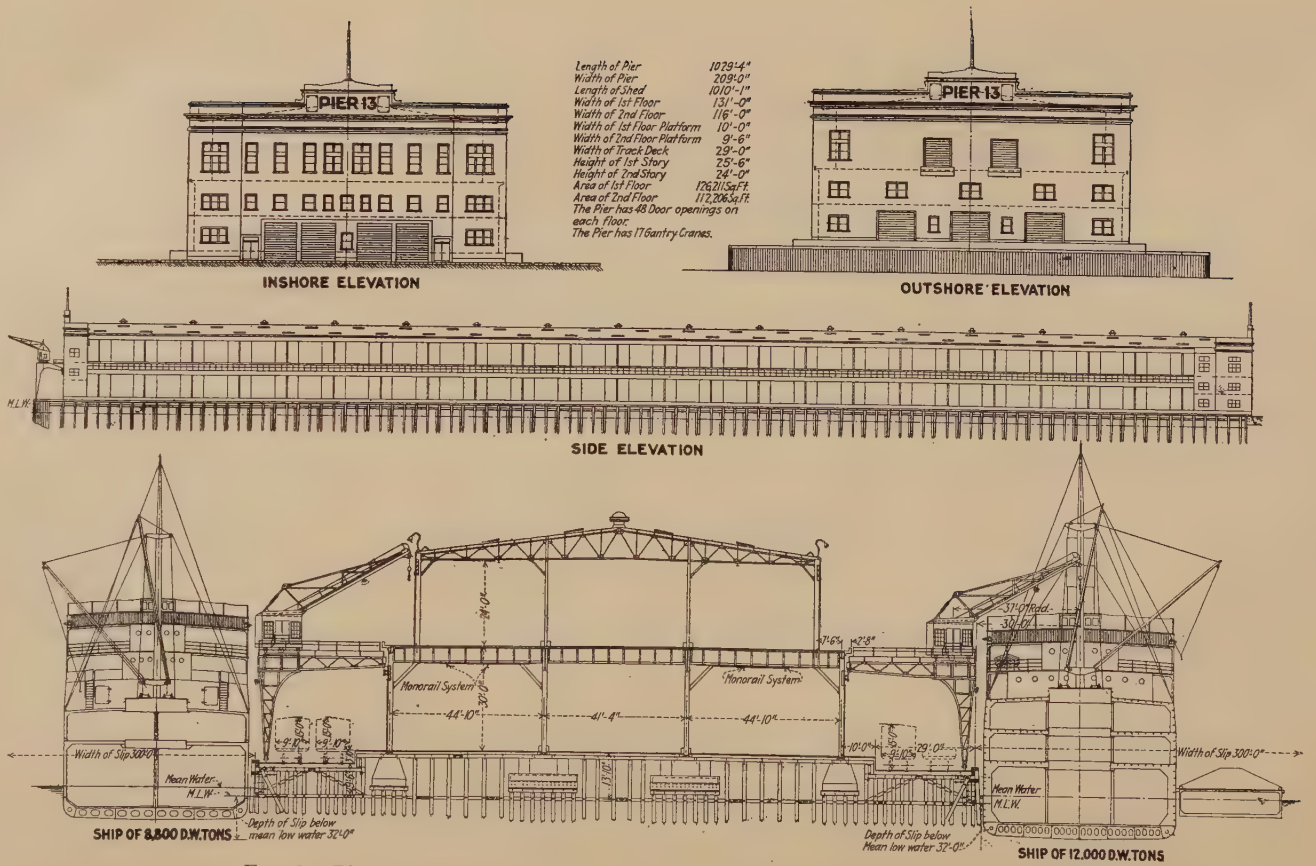


FIG. 8.—Piers 12 and 13, Staten Island, show a sincere effort at modernization.

One pier is 62 feet wide.
Four piers are 60 feet wide.
Four piers are 50 feet wide.
Two piers are 45 feet wide.
One pier (which cannot be termed anything but a dump) is only 40 feet wide.

Practically all of these piers are more than 25 years old, and in many instances the inshore ends, that is out to the pier-head line of 1871, are 40 to 45 years old.

The slip widths of these thirty-four piers are as follows:

One is 200 feet wide.
Three are 190 feet wide.
One is 185 feet wide.
One is 180 feet wide.
Two are 175 feet wide.
Five are 165 feet wide.
Four are 160 feet wide.
Three are 155 feet wide.
Two are 150 feet wide.
Two are 145 feet wide.
Two are 140 feet wide.
The "dump" is 102 feet wide.

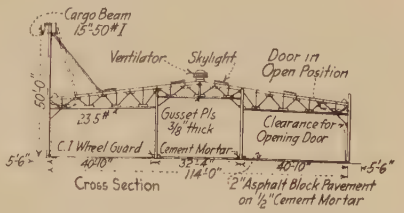
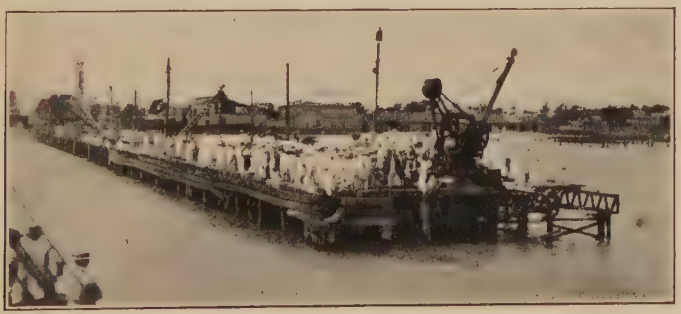


Fig. 9.—Pier Type No. 1. Sections and elevations of pier with one-story shed. Staten Island, N. Y. Municipal Piers. Common Type.

The narrowest pier to be erected in the new development on Staten Island is 125 feet wide, with railroad connections, if and as desired by tenants, and the slips will have a width of 300 feet.

The pierhead line between the Battery and Gansevoort Street has been extended on three occasions since 1871, and the piers have thereafter been carried out to the pierhead line as extended, without ever widening the piers or widening the slips.



(Photograph by the Author.)

Fig. 10.—Small, uncovered pier at Progreso, Yucatan, equipped with rail tracks and cranes to handle baled sisal from cars to lighters. Ships anchor 2 to 4 miles offshore. This method of lighter discharge is quite universal in Caribbean and West Coast of South American ports.

Can anyone testify more eloquently as to the cause of congestion on the North River docks and marginal street south of the more modernly constructed Chelsea piers?

Next May (1921) the Dock Department will celebrate its fiftieth anniversary. What could be a more appropriate ceremony than the inauguration of a movement for the modernization of these piers? (See Frontispiece.)

THE QUAY SYSTEM

Type 2*a*. The Quay and Basin System

Advantages of the Quay System.—The claim that a pier system affords more berthage is true only under certain conditions. Obviously, if all piers were removed from the Manhattan waterfront and marginal quays substituted, a great loss in berthage space would result. However, the New York side of the port of New York and the New Jersey side along the Palisades are abnormal. To go out to Jamaica Bay, Newark Bay, Bayonne, Staten Island, or many others places where vast areas of lowland and shallows are putty in the engineer's hands and there slavishly reproduce the piers evolved by Manhattan's special conditions would indicate the possession of a Chinese imagination.

An example in figures will show that, on a large scale development, the quay and basin system will give the greatest berthage and more efficient berths in operation.

Assume a large area of dredgable lowland for a port terminal development on a comprehensive scale. To make it more easily visualized think of upper New York Bay, Bayonne shore line. The first cost of the terrain may be assumed as low. Suction dredging is most efficient with large areas to be filled with the spoil. Reclaimed land in quay-piers 500 by 5,000 feet is efficiently filled with suction-dredge spoil. There are few harbors with sufficient natural depth, and dredging is necessary under nearly all conditions. The new land forms a means of disposing of the dredging spoil and itself becomes a valuable property because of its new deep-water frontage. Thus new values are created in return for dredging expense.

It requires a little figuring to demonstrate that in a large-scale development the pier and slip system affords less berthing space for ships than the basin and quay system. In the example of the Bayonne shore of New York Bay from Communipaw to Kill van Kull, for the sake of argument, disregard any rocks and reefs or other hindrances of dredging that may or may not be present. Assume the general dimensions as follows:[1]
Average distance from present dry land to army pierhead line, 5,000 ft.
Length of pierhead line to be developed, 15,000 feet.
Established pier length, bulkhead line to pierhead line, 1,200 ft.

Question—Which development will give the most berthage? Quays and basins, or piers and slips? (Fig. 11).

[1] Actually the distance from Communipaw to Constable Hook is about 18,000 feet. The established *bulkhead line* at a point north of the Pennsylvania Railroad Greenville piers, is 9,000 feet from the shore, and just south of the Pennsylvania Railroad piers the distance is 11,000 feet. In such a development as here described the Chief of Engineers would doubtless grant extension of quay piers to the *pierhead line*, 1,200 feet more.

The quay and basins plan would work out as follows: Assume a land section to be 750 feet with ten one- or two-story sheds (475 by 150 feet) on each quay, two rows of warehouses inshore, a lighter canal down the center, and railroad tracks according to modern practice back of sheds, a drayway down the center line of the open ground floor of the warehouses. The outshore end of this quay pier will carry car float bridges and ferry

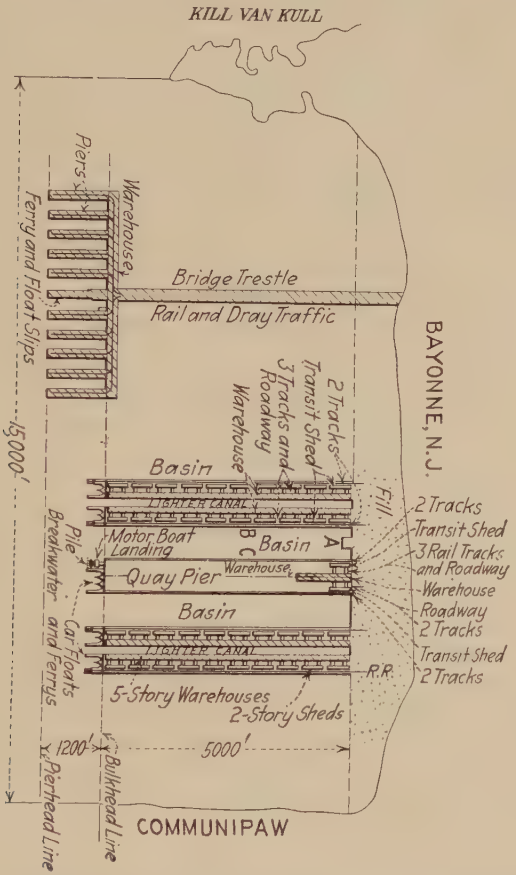


FIG. 11.—Quays give much more berthage than piers in large terminal developments. Contrast pier system above with 160 berths and quay system below with 240 berths.

slips for cartage and passenger connection with Manhattan and Brooklyn. The basins are 700 feet wide and the quay piers 800 feet wide, a total of 1,500 feet for each unit. A motor-boat ferry service for passengers only will connect the various parts of each basin, or a jitney service on land, or both.

Mooring posts or dolphins down the center of basins will afford sheltered berthage to accommodate ten to twenty 500-foot vessels discharging "in stream," awaiting quay berths, undergoing minor repairs, or laying

up for other reasons. There is a great lack of such accommodation at most ports, piers being misappropriated for this use. Such a unit includes every element of a well-designed port terminal. The water frontage of 15,000 feet will accommodate ten such units, or 200 completely equipped berths of 500 feet each and as many more "in-stream" moorings. The Chief of Engineers would probably consider such construction as piers and permit extension to the pierhead line. This would add 40 more berths or 240 in all.

With Piers.—The plans for a pier system development which were conspicuously featured several times in Sunday supplements of New York dailies and are not introduced here as a joke, contemplated the following layout:

The United States Engineers' pierhead and bulkhead lines are established. In order to make a Chinese copy of the Manhattan waterfront a trestle was to be built out from Bayonne to a filled strip of land behind the established bulkhead line. The layout mentioned did not include warehouses on this land. They could be built back of the bulkhead. Thus would be reproduced the narrow pier system of Manhattan, or, with widening, the warehouse system at South Brooklyn Army Base, reached by a trestle a mile long. The division of the waterfront and berthage on the generous scale might be as follows: piers, 125 by 1,200 feet; slips, 275 feet; or 400 feet of waterfront per unit. This would give a total of 40 piers and slips on this waterfront. Theoretically, each pier would berth four vessels of 500 to 600 feet each, a total of 160 berths, but in practice only two such vessels, and frequently only one, can be economically worked at such a pier. If the limit of four vessels per pier is assumed, the quay system would have the advantage of accommodating 40 more vessels to the bulkhead line and 80 more to pierhead line. Inasmuch as the quay system assures maximum use of the waterfront without congestion, while a pier could work only two large cargo ships at one time, the workable quay berthage would be approximately 240 for the quay as against 80 for the pier layout. In addition, the quay system layout includes all the elements of a complete terminal while some of these important features are lacking in the pier system.

Also, it may be added that, by reducing the warehouses on each quay pier from two to one, and reducing the width of the quay pier from 800 to 600 feet, two more units could be constructed on the same harbor frontage, adding twenty-four more berths for 500-foot ships for each quay pier—making a total of 288 workable berths as compared with eighty at piers. One row of warehouses would be adequate for the berthage space. But in this particular development, with the direct rail connection inland over eleven railways, a second row of warehouses could well be provided to be used for rail terminal stores to serve other parts of the port of New York by lighter.

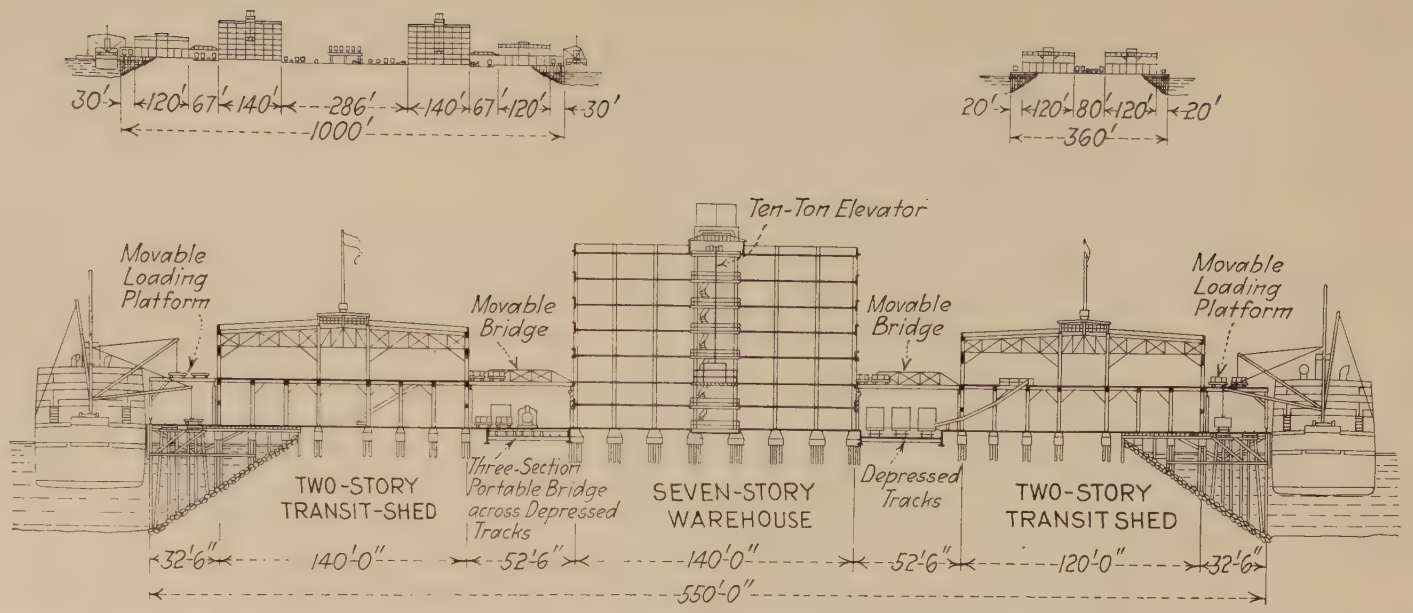
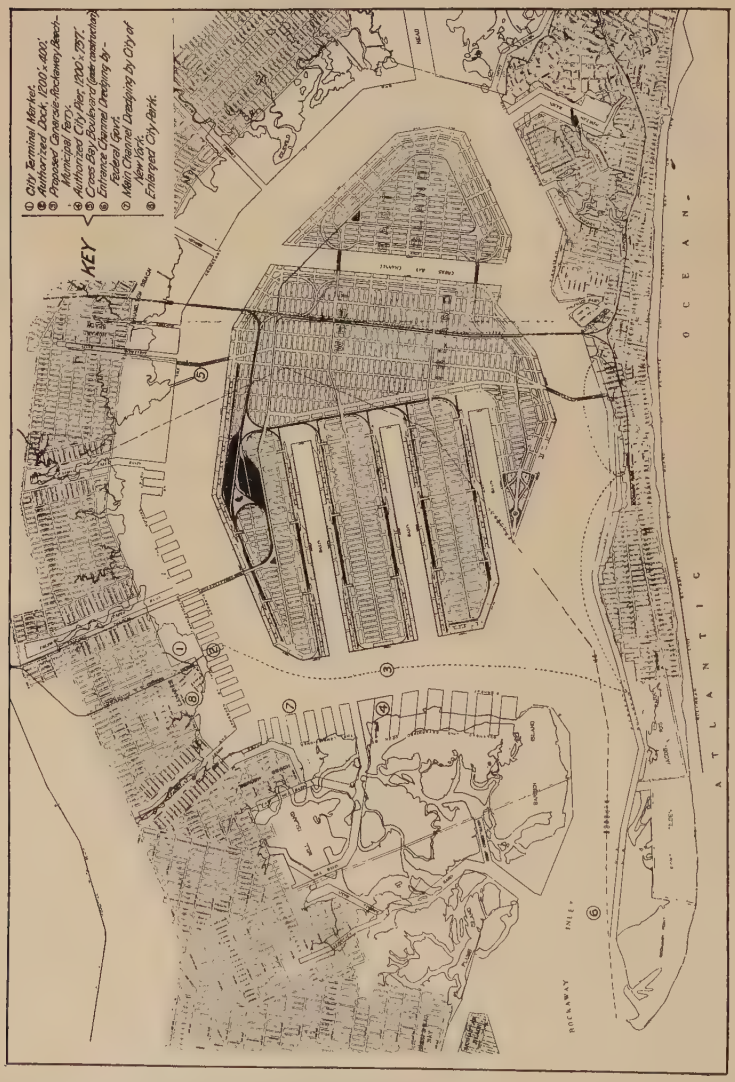


FIG. 12.—Quays and Basins projected for the Port Terminals, Oakland, California, according to Hamilton Higday and G. F. Nicholson. These are striking examples of the double quay in a quay and basin type.

It is therefore obvious that, aside from other advantages, the quay and basin system, under conditions of large development of dredgable land, will give the greatest berthage. In addition, the system offers other advantages.


KEY
① City Terminal Market.
② Authorized Dock, 1200'x 400'.
③ Authorized Dock, Rockaway Beach—Municipal Ferry.
④ Authorized City Pier, 1200'x 257'.
⑤ Cross Bay Boulevard (part constructed).
⑥ Entrance Channel Dredging by—Federal Govt.
⑦ Main Channel Dredging by City of New York.
⑧ Enlarged City Park.
OCEAN
ATLANTIC
ROCKAWAY INLET

(*Plan October*, 1923.)

FIG. 13.—Basin and Quay type proposed for Jamaica Bay, Long Island, N. Y. Basins 2 1/16 miles long, ca. 11,000 feet—and 1,000 feet wide flanked by modern quay equipment on reclaimed land areas two-thirds of a mile wide, ca. 3,500 feet. The authorized piers at (2) are 1,200 by 400 feet, *i.e.*, double piers larger than those at the Norfolk Army Base.

Other Advantages.—The two chief advantages of the quay system in moving freight are the decrease in congestion and the shorter trucking movement.

The decrease in congestion is due to the fact that the merchandise discharged from the ship's hatches may be sorted and piled approximately

opposite to the hatch and, when called for by dray or freight car, be loaded to the street side opposite the point of rest on the wharf. In the pier layout either drays must drive onto the pier, intolerably increasing congestion, or the merchandise must be trucked to the headhouse, if one has been provided. These and other advantages to economical operation and dispatch will form a large part of the discussion throughout this work (see also Figs. 12, 13 and 14).

(Courtesy of U. S. S. B.)

FIG. 14.—Type No. 2*a*. (Quay and Basin System.) Quay and basins at Hamburg, Kuhwärder Basins. From right to left are Ellerholz Hafen, Mönckeberg Quay, Kronprinz Quay, Kaiser Wilhelm Hafen, Augusta Victoria Quay (in left distance) Gravenhof Bank (Ufer) Kuhwärder Hafen.

TYPE 2*b*. MARGINAL QUAYS

An example of a true quay system is that of Rio de Janeiro (Figs. 15–16).

The port of Rio de Janeiro has a quay 3355.25 meters long, built of stone, masonry, and cement upon a compressed-air caisson foundation. The depth of water alongside these quays ranges from 27 to 33 feet at low tide and from 35 to 41 feet at high tide.

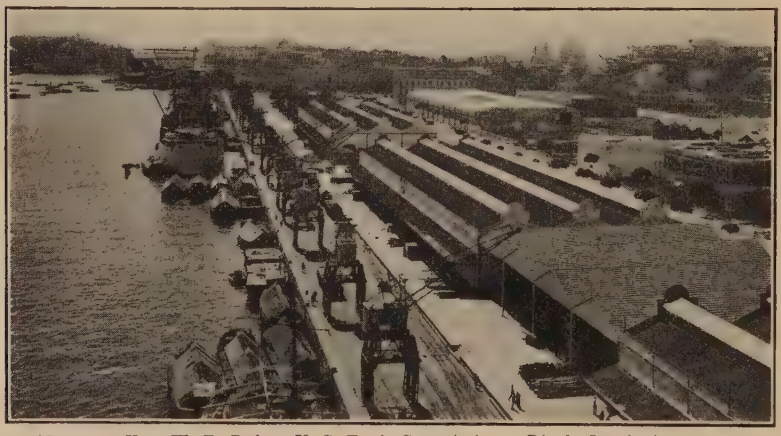
From the top of the caissons to low-tide level the external casing of the quay is constructed of chiseled stone.

The foundation consists of 134 caissons lowered into thick sand, stone in decomposition, or rock. Nine types of caissons are used, all of 6.60 meters width at the top, the width at the base varying between 6.60 and 9.60 meters; and the height between 2.50 and 10 meters. Each is of 25 meters length.

There are mooring posts every 25 meters in the center of each caisson; ladders every 150 meters and three stairways cut into the quay, each in two flights.

The quay is 100 meters wide, 25 meters of which are given over to railway lines, 35 meters to warehouses, and 40 meters to public transit.

In the strip of 25 meters allotted to the railway lines there are three tracks of three rails each that carry cars of both 1 meter and 1.6 meters gage. There is also a line of rails of 4.50 meters gage for the cranes, the outer rail being near the edge of the cap and the inner rail between the first and second set of mixed tracks.



(Courtesy, Hon. W. E. Embry, U. S. Trade Commissioner, Rio de Janeiro.)

FIG. 15.—Type No. 2*b*. Marginal Quay. This shows passenger landing used by all seagoing passenger ships. The Steamship *Pan America* is seen tied up at Berth 18, which is the most convenient and desirable landing place. The *Puaca* seen in the middle of the picture leads into Avenida Rio Buanco, Rio's main business thoroughfare. The large white pavilion in upper right center of picture is American Industrial Building during Exposition. Note 82-foot wharf apron and two gages of railroad tracks. Ninety traveling, full arch, gantry cranes of 4.50 meter gage (14 feet 9 inches).

The strip 35 meters wide is allotted to completely equipped warehouses, of which there are eighteen, each measuring 100 meters in length by 35 meters in width by 8 meters in height; ten being of brick masonry, seven of reinforced concrete construction and brick masonry, and one of brick masonry and armoured cement. Each of the warehouses is equipped with overhead electric traveling cranes of 1½ tons capacity, there being a total of 158 of them; also with electric lights, sanitary fittings, furniture, and all other modern warehouse equipment.

The 25 meters strip previously referred to, carrying the rail lines, is equipped also with 90 traveling cranes of 4.50 meters gage. There are eighteen cranes of 5 tons capacity each, eighteen of 3 tons capacity each, and fifty-four of 1½ tons capacity each. In addition there are three steam cranes, two of 10 tons capacity each, and one of 20 tons capacity.

Fig. 16.—Map of port works of Rio de Janeiro.

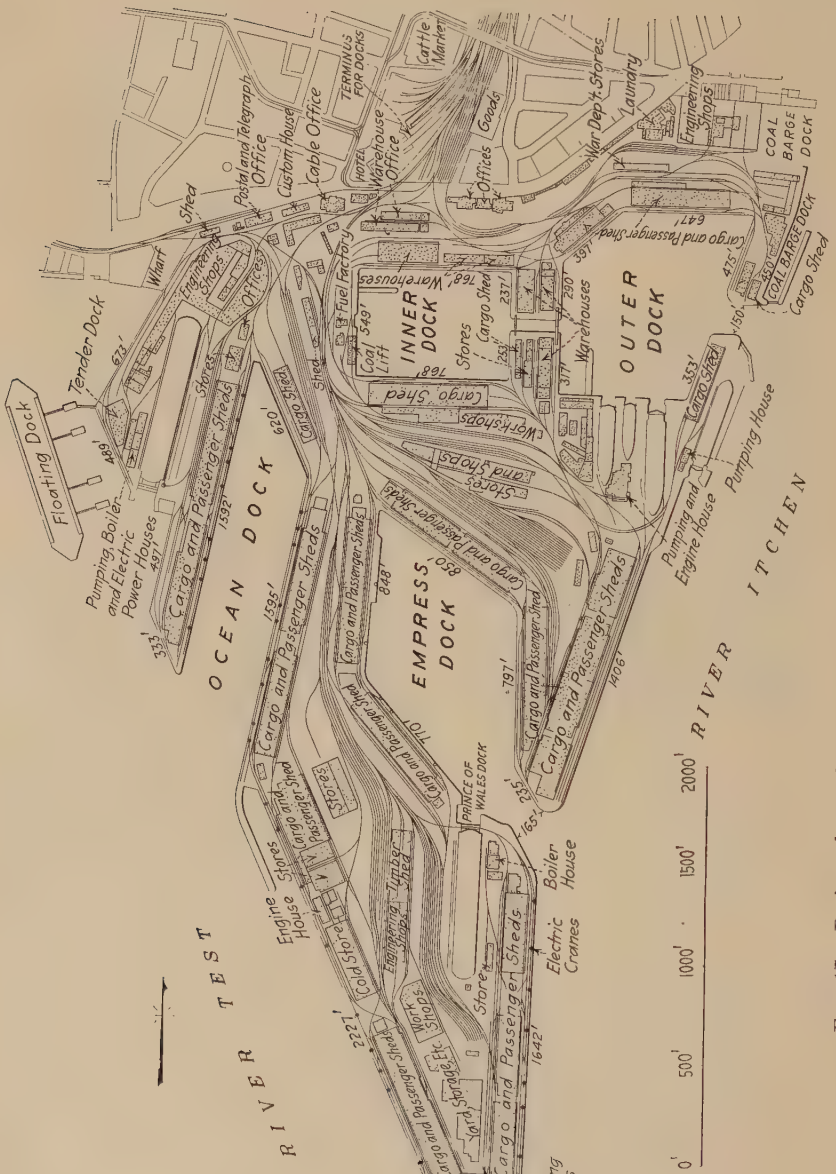


Fig. 17.—Basin and quay layout of the modern ocean liner port of Southampton.

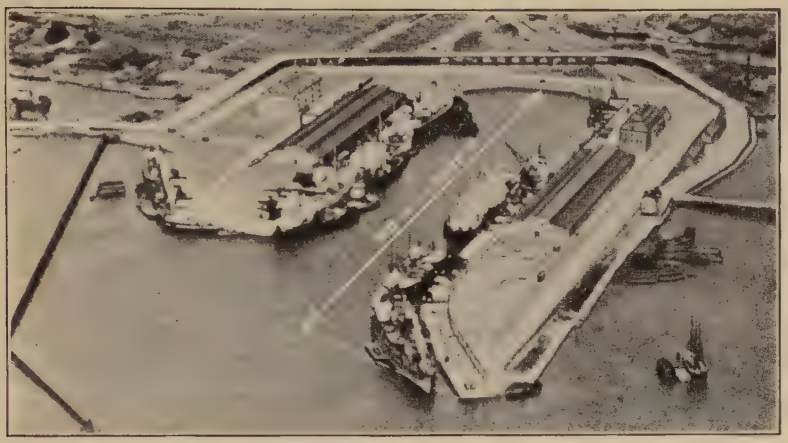


FIG. 18.—Quay and basin type, 2*a*, in a smaller edition. An aerial view of the completed section of the Free Harbor of Gothenburg, Sweden.

FIG. 19.—Type 2*a*. Wet docks and basins at Antwerp.

Type 3. Double Pier and Slip System

The discussion of the width of piers also involves the question of length. The length of piers depends on the War Department in the United States. At New York and elsewhere 1,000 feet is about the limit allowed, although in South Brooklyn there are piers of 1,700 feet. There are, however, certain considerations of an administrative nature which affect the economy of length. *The longer the pier the wider it must be.* The reason for this is that the longer the pier is, the more traffic must be handled at the bulkhead end. Its length increases the number of cars and battery trucks which go onto the pier, and if teaming is allowed the longer the pier the more cargo there is and the more teams will be needed.

On the other hand, the *wider the pier the longer it must be.* The more waterfront the pier occupies the longer it must be in order to attain the maximum berthing space. There are several things to be considered here.

When a pier becomes longer than 1,000 feet it is uneconomical to move freight by hand or electric truck to the bulkhead for loading into railway cars or drays. When either teams or freight cars are admitted to the pier the space for sorting and handling is greatly reduced. Unless the pier is widened, congestion grows rapidly with the length of the pier.

When a pier is longer than 1,000 feet the pier slip must be wide enough to pass large ships beyond a ship berthed near the channel end, but not occupying all the berthing space. The pier and its slips must be of a much greater width as soon as the one ship per slip limit in length has been reached. With accommodation for ships of about 11,000 tons gross, quays or piers would be 500 feet, 1,000 feet, 1,500 feet, 2,000 feet, or some other multiple of 500.

It therefore becomes necessary to depart entirely from the Chelsea type of narrow pier construction and go to another design. The enlargement of the Moyamensing design at Philadelphia would give two rows of sheds with teaming and railroads between. Such a pier would be uneconomical of waterfront unless made fairly long. Once it is made wide it may be made several thousand feet long as in the quay and basin types 2*a* and 2*b* just discussed.

This is only possible where the water is wide and shallow to permit pile-fill structures with dredged deep water between, or a low and soft shore to permit excavation of the slip into the land. To arrive at a compromise, perhaps it is better to call it a happy medium, there has been a decided leaning towards the double pier (Type 3). When very large this may be called a quay pier or Type 4. There is no line of separation unless the arbitrary one of 1,200 feet length is assumed.

The question of double pier (3) or quay pier (4) is largely a matter of degree in the development of the principle of parallel elements as contrasted with supporting elements at a right angle with the wharf and ship.

Type 4. The Quay-pier System

The quay pier, or large double pier, seems to have received an overwhelming majority of votes in the more recent port facilities constructed

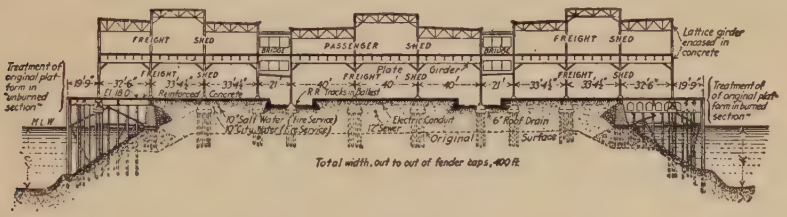


Fig. 20.—Double pier type 3. Commonwealth Pier, Boston, Mass. The middle section is an almost total loss in operation, being cut off from ship side by the depressed tracks.

and planned throughout the world. The quay pier is especially popular on both sides of the Pacific from Seattle and San Francisco to Kobe, Osaka, Auckland and, in fact, back to the great new Gladstone Docks at

(*Fairchild Aerial Survey, Inc.*)

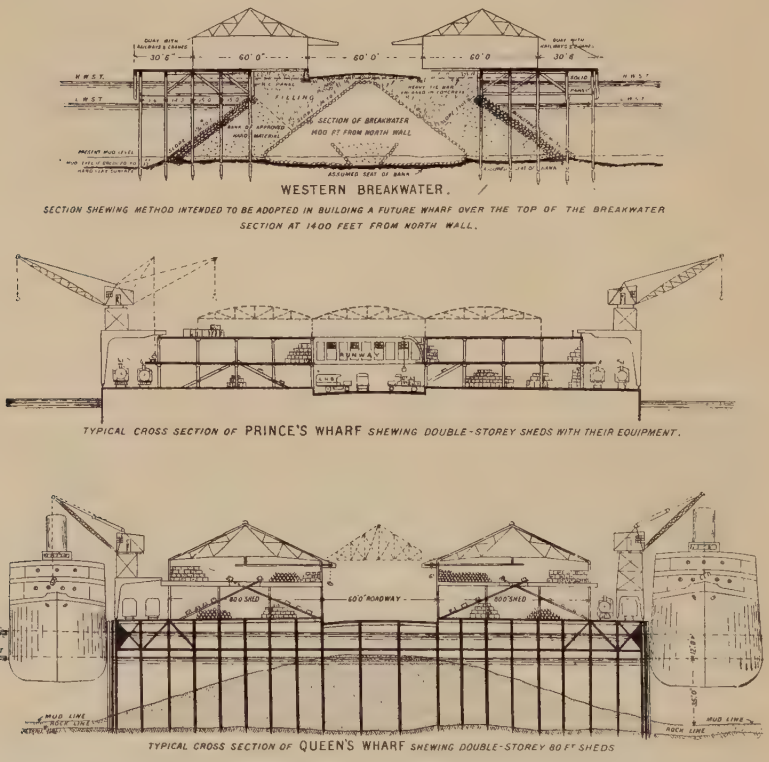
Fig. 21.—Union Pier, opened 1925, Charleston, S. C. The type 3, or double pier system is very pronounced, being 417 feet 5 inches wide by (666) (692) feet long. The outer berth across the pierhead is used by the larger 10,000-deadweight-ton freight liners that dock and shove off without tugs. Of special note are the four middle tracks. This enables spotting of two strings for each shed. The south slip has no ship side track as this berth is fitted with drop ramps for coastwise vessels. Sheds are 40,500² feet and 37,000² feet. Inshore end at present used for open storage.

Liverpool. The figures tell the story better than words. The dimensions are available in the tables of comparative dimensions.[1] (Figs. 20 to 26.)

[1] Table I.

Type 5. "The Trunk and Branch" or "Herringbone" System

The city of Tacoma, Washington, has developed a new port terminal layout which combines many good features in a new form. Because of its peculiar shape the author has given to it the name of "trunk and branch." It might also be called the "herringbone" layout. The system was first mentioned by Gen. W. M. Black in 1919, and found a


WESTERN BREAKWATER.
SECTION SHEWING METHOD INTENDED TO BE ADOPTED IN BUILDING A FUTURE WHARF OVER THE TOP OF THE BREAKWATER
SECTION AT 1400 FEET FROM NORTH WALL.
TYPICAL CROSS SECTION OF PRINCE'S WHARF SHEWING DOUBLE-STOREY SHEDS WITH THEIR EQUIPMENT.
TYPICAL CROSS SECTION OF QUEEN'S WHARF SHEWING DOUBLE-STOREY 60 FT SHEDS

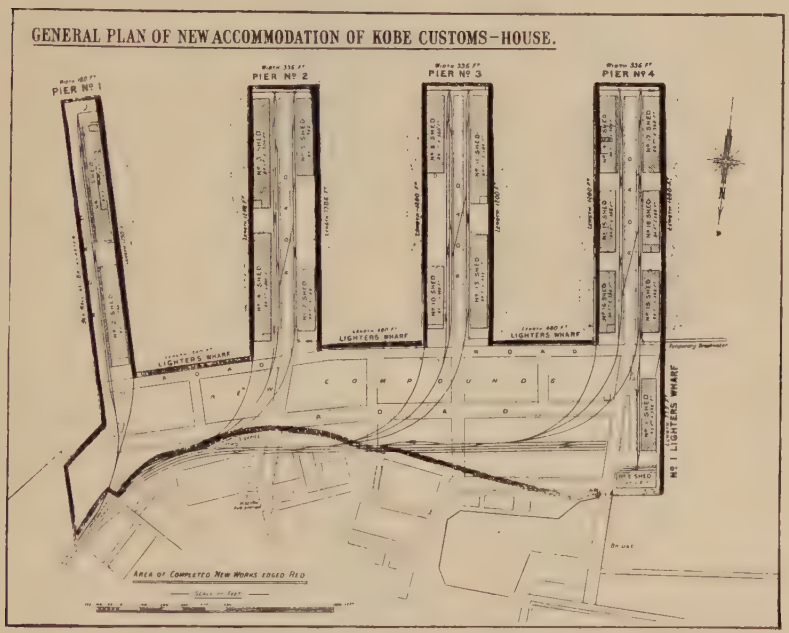
(Courtesy of Dock and Harbour Authority.)

Fig. 22.—Types 3 and 4 at Auckland, N. Z. Double piers predominate, the Western Breakwater Wharf (projected) assumes the proportions of a full-sized quay pier.

warm advocate in Captain Hoffman, C. of E., U. S. A. The arrangement is more quickly understood from the illustration (Fig. 27). It is a combination of the pier and slip and the double quay and basins systems. Given a soft upshore with a bay frontage of 4,000 feet, two basins 500 and 800 feet in width are dredged with several oblique slips 300 by 1,200 feet. One filled area is a large merchandise quay pier 1,200 by 936 feet with two transit sheds and a center line warehouse. Another filled area is a double pier 1,200 by 710 feet. Another is an open wharf 1,200 by 376 feet. The center area, or trunk, carries rail connections and

storage yards to the piers, tank storage yards for bean oil, and could carry a grain elevator, cold storage, and other supporting warehouses. The area marked "Industrial site" at the foot of "Slip 2" should never be turned over to any private manufacturing plant. It is too valuable as a warehouse site or especially a lighter wharf. The entire design gives the advantages of both pier and quay layout within a compact, restricted area.

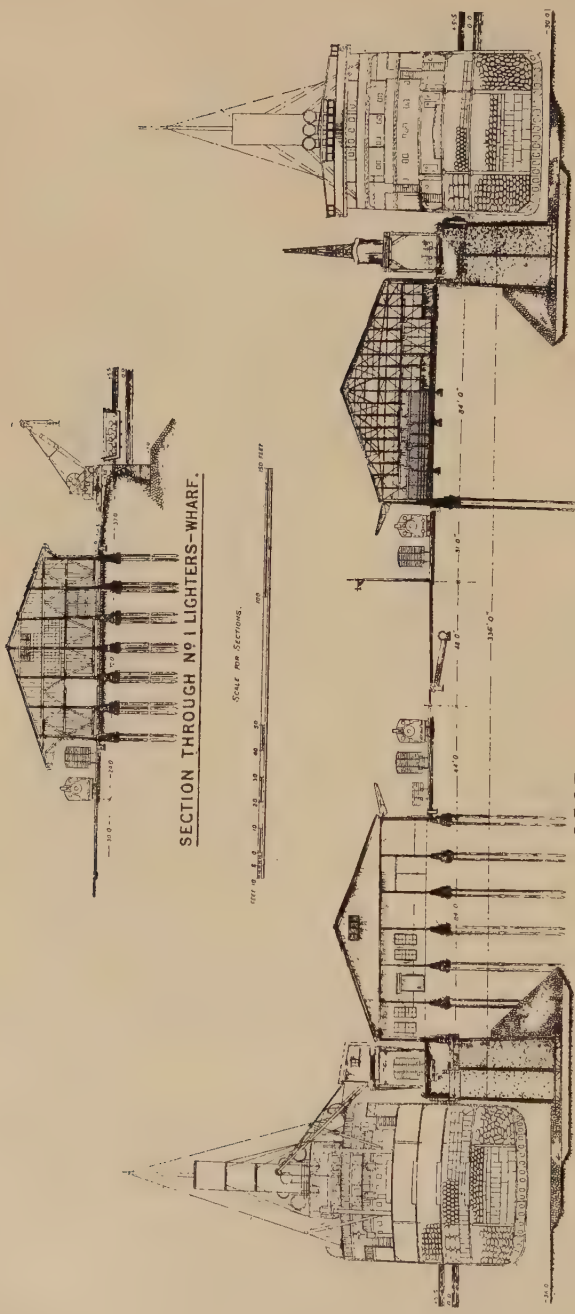
Another example of the trunk and branch layout, but with a very large trunk and on a huge scale, is the terminal of the Central New Jersey Railroad at Communipaw, Air View (Fig. 28).



(From Dock and Harbour Authority, London, January, 1923.)

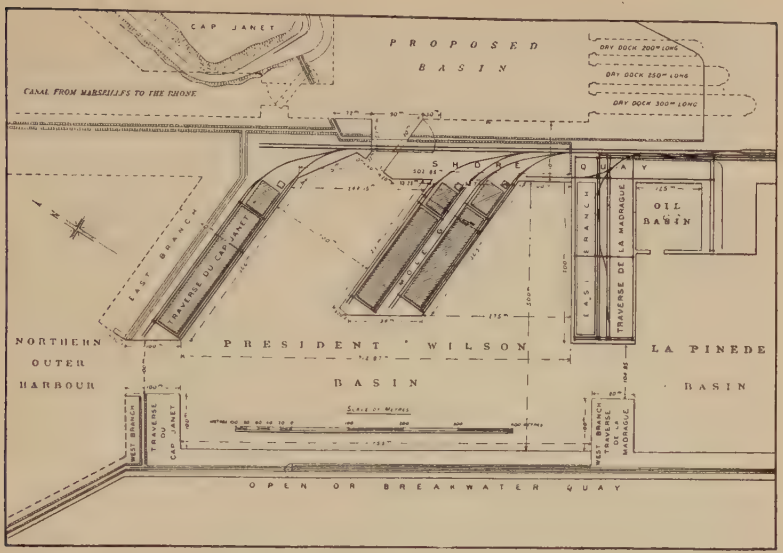
FIG. 23.—Type 4. Quay-pier system at Kobe, Japan. Piers 1,200 by 336 feet. Slips 480 feet wide.

A trunk and branch type of wharf construction, but on rather small dimensions and with the branches at right angles to the trunk, is found in the Queen's Wharf at the Port of Wellington, New Zealand. In this case, the trunk with its branches is built out into the natural harbor. This method enabled a concentration of shipping near the center of business, the custom house, with a minimum waterfront. As the port has developed, the pier types in increasing sizes and with more extended equipment have developed with a typical modern marginal quay of the bulkhead or, as they call it in Wellington, the "breastworks" type. This



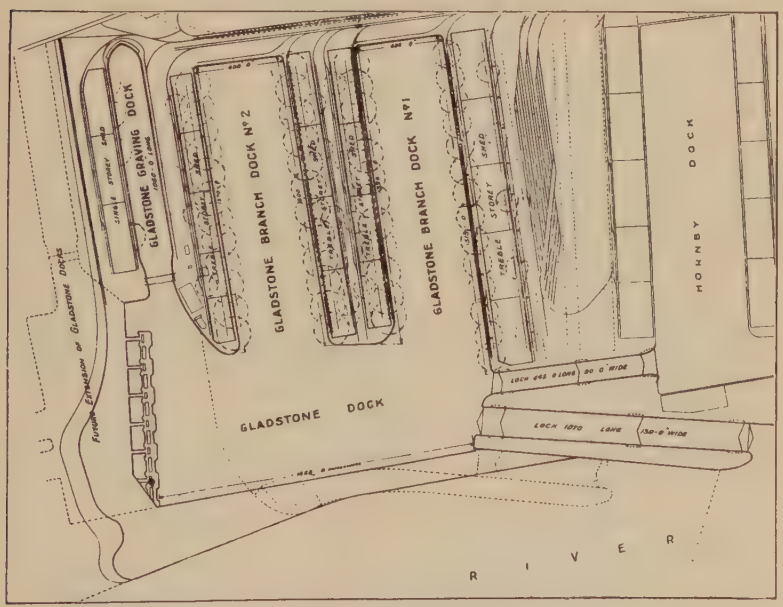
(*From Dock and Harbour Authority, London.*)

FIG. 24.—Type 4. Quay pier, Kobe, Japan.



(*Georges Sainflou, Ingenieur Ordinaire des Ponts et Chaussees at Marseilles in Dock and Harbour Authority, October*, 1924.)

FIG. 25.—Quay-pier construction within dock basins at Marseilles.



(*Courtesy of Mersey Dock and Harbour Board.*)

FIG. 26.—Plan of Gladstone dock system, Liverpool. Wet dock and two branches with quays and quay pier 1,325 feet long by approximately 380 feet. Quays have 54 feet of water alongside maximum high water. Equipment of all quays, lineal frontage $2\frac{3}{4}$ miles, is 54 acres of floor space in three-story sheds and flat roofs. Thirty-one gantry cranes at 3 tons each.

proposed quay will be 2,709 feet in length. There seems to be no prejudice for or against any one type of wharf as all are used according to the convenience of natural conditions of terrain.

Type 6. The Square Pier

The square pier is a recent project for Baltimore and also the old port of Savannah. Both disclose a peculiar layout. The slips, 1,200 to 2,000

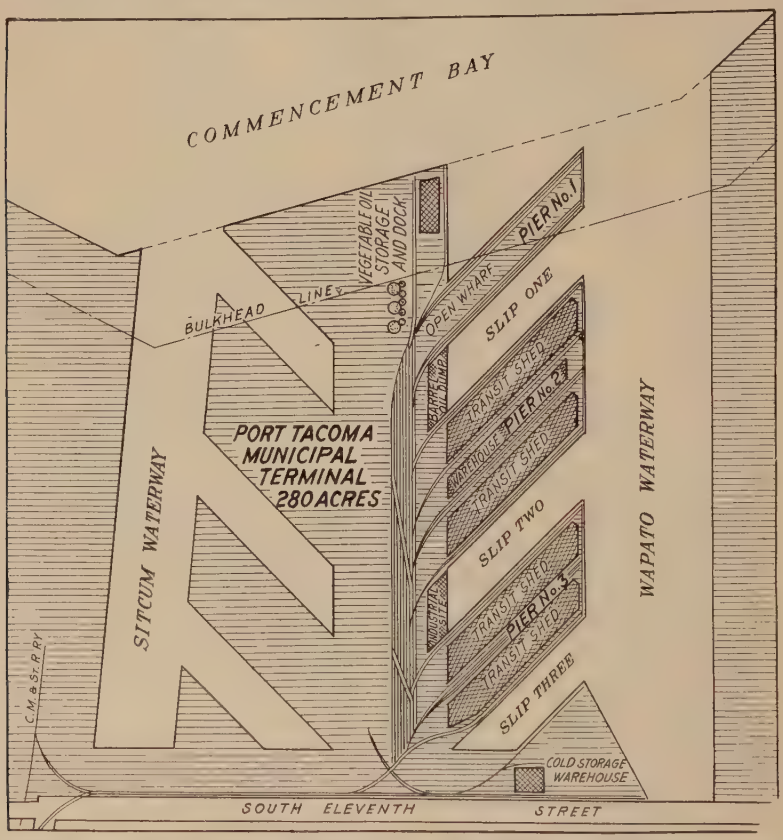
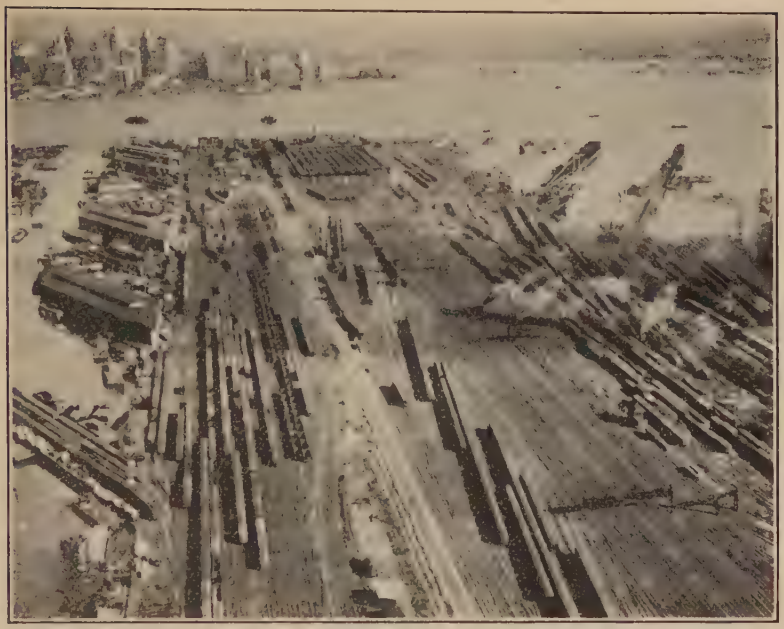


Fig. 27.—Type 5. Trunk and branch or Herringbone system of terminal arrangement as illustrated by facilities erected recently at Tacoma, Wash. This is a combination of the "Quay and Basin" with the "Pier and Slip" and the "Quay-pier" systems. Also the angle pier is illustrated.

feet deep, and in the new design 300 feet across, are dredged into the fore shore at wide intervals, leaving a solid fill wharf, warehouse, open storage and railroad area as broad as it is long. The terminal area is a square with equal berthing space on three sides, one the river and two toward the two slips. The object is to obtain the greatest possible freedom of operation back of the wharves with ample storage space within the shortest trucking distance from any hatch of any ship berthing at any point around



(*Photograph by Fairchild Aerial Survey Corporation.*)

FIG. 28.—Type No. 5. Trunk and branch terminal layout with special accent on the very wide *trunk* carrying about 75 parallel tracks besides crossovers. Yards of the Central New Jersey Railroad at Communipaw.

(*Photograph by Eaton-Ison Company.*)

FIG. 29.—The No. 6 Square Wharf type at Savannah, Ga. In middle distance right, can be seen the warehouses (single story) in a hollow square of wharves on three sides formed by the river roadstead and two dredged slip basins. This is a type of construction receiving considerable study.

(Courtesy of M. Dubiet. Photograph by the Service Photographique Aviation, Aviation Tunisienne.)

FIG. 30.—Square basin and quays. Port of Tunis, French Protectorate, N. Africa. A basin 300 by 400 meters with quay walls on three sides.

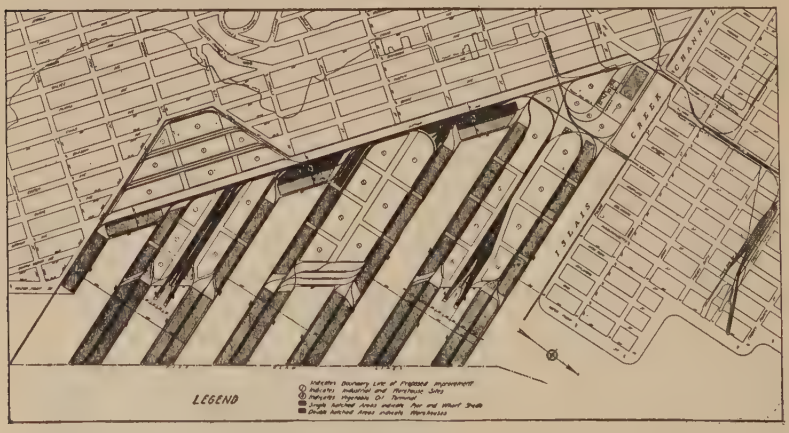


FIG. 31.—Type 7. The "Oyster Fork" type of quay pier. A compromise with the established bulkhead and pierhead lines, yet giving the advantages in the development of a large, dredgable area on the basin and quay principle.

the sides of the square. The early development of this type at Savannah was doubtless due to the necessity for a large, open storage space for naval stores (turpentine and rosin) within easy distance of the loading point. No modern structures on the square pier system have yet been operated to demonstrate its general efficiency (Fig. 29).

The "Commonwealth" and "Fish" piers at Boston are an approximation to the square pier as each has a large court yard within the pier area giving free room for teams and drays. In this case, however, there is not a saving of expense resulting from few slips dredged inshore because of the greater quay pier width, but, on the contrary, the cost of these very wide piers built out from the shore is enormous because of their great width. With dredged slips the square pier is an economical and practical form of construction. In a wholly constructed pier it is an unusually heavy expense.

The architectural features of Commonwealth pier are notable as well as the cold storage warehouse of the "Fish Pier." Also the approach for vehicles to the Commonwealth pier is over a viaduct to the second deck thus crossing the railroad tracks above grade.

The square basin is a modification of the square pier. In operating principles it is not different from the usual quay system. Two widely separated examples of the square arrangement are illustrative, one at Savannah (Fig. 29) and one at Tunis (Fig. 30).

Type 7. Oyster Fork Quay Pier

This (Fig. 31) type might also be termed a "bootjack" form. Because of established government bulkhead and pierhead lines and the tendency toward the quay-pier and slip design in modern construction this form will doubtlessly be met with frequently. The quay pier proper and basins extend inward from the bulkhead line. Being solid fill and of great width the main fill is not permitted to extend farther into the river or bay. Therefore, two piers of usual dimensions are extended from the bulkhead to the pierhead line forming a two-pronged fork. The characteristics of middle unit China Basin are:

	Feet
Total width quay pier	1,100
Total length quay pier (foot of slip to street)	2,400
Total length basin (end of pier to bottom of basin)	3,300
Total width of basin	400
Total width of slips between piers	400
Total length of slips between piers	1,120
Total width of each pier (2 times 350 feet plus 400 feet equals 1,100 feet)	350

Alternate Oyster Fork Quay Piers accommodate railroad lead tracks to a car-float bridge at the bottom of the slip leading to a classification yard. The space is taken from the warehouse site.

TABLE I.—CHARACTERISTICS AND DIMENSION

Location and type	Wharf			Width of apron wharf	Number and location of railroad tracks	
	Length and width in feet and inches	Type of construction	Dock or slip dimensions		Number on apron	Total on wharf
Amsterdam						
Commercial Quay	7,260′	Masonry wall and fill	Y dock 675′ wide	Wide 40′ (?)	1	2
Sariname and Levante Quays		32′ deep		Wide		
Java Quay	3,333′	32′ deep		Wide	1	5
Sumatra Quay (Y Island)	3,933′	32′ deep	Y dock 675′ wide	Wide	1	
Borneo Quay	3,380′					
Municipal Bonded Stores						
Aukland, N. Z.						
1924 Princes Wharf	1,230 × 280′	Double-pier, pile and fill	35′ deep	30′ 6″	2	2
Queens Wharf	1,230 × 280′	Double-pier, pile and fill	480′ wide	30′ 6″	2	2
Central Wharf	800 × 240′	Double-pier, pile and fill	350′ wide	30′ 6″	2	2
King's Wharf (connecting 532′)	820 × 240′	Double-pier, pile and fill	31′ deep	30′ 6″	2	2
Brussels						
Opened ocean shipping, 1922				12 to 18′	2	7
Brisbane						
Hamilton Development						
River Quay	5,800′	Solid fill	600′ to mid river	33′	2	3
Basin Quay	4,350′	60′ pile apron	735′	33′	2	3
Three piers (branch docks)	1,900 × 280′	Solid fill	1 à 550′	33′	2	6
	1,500 × 280′	60′ pile apron	3 à 350′	33′	2	6
	1,000 × 280′			33′	2	6
Bombay						
Alexandra Dock with branch deck	Two quays à 2,500′	Masonry and fill, wet docks tidal range	1,025′	Vary around 50′	1 or 2	4 each quay
	Quay pier 1,600 × 425′	18′ 7″	Two branches, 300 and 350′			8 each pier
Bremen						
No. 1 dock, two quays (water 29′ 5″)	316′, 6″ × 4,500′	Excavated basin and quay system	Basin dock	36′ 2″	2	5
	316′, 6″ × 4,500′	Masonry wall and solid fill	360′ × ca. 6,200′	36′ 2″	2	5
No. 2 dock, two quays (water 36′)	412′, 3″ × 5,333′	Masonry and fill	360 × 5,660′	55′ 8″	3	6
	412′, 3″ × 4,000′			55′ 8″	3	6
	Small quays { 55′, 216′, 75′, 65′					
Bremerhafen						
Kaiser Hafen No. 1	8,250′	Excavated docks		ca. 50′	3	ca. 7
Kaiser Hafen No. 2	1,650′	Quays, masonry, and fill		ca. 50′	3	ca. 7
Kaiser Hafen No. 3 (For ocean vessels)	3,960′			ca. 50′	3	ca. 7
Bahia						
(opened 1913)	3,300′			16′	3	None

TYPICAL MODERN MARINE TERMINALS

Cargo transfer equipment		Transit sheds				Drayway, width in feet	Warehouses	
Main	Auxiliary	Dimensions and area	No. of decks	Heights, areas	Deck loads, lbs. per square foot		Stories, deck loads	Dimensions, length and width
elec. cranes ll portal ½ at 6 tons	1 à 30 tons	.....	1	?	.....	Both sides	None	.....
elec. cranes, at 8 tons	1 à 30 tons hammer-head	6 sheds à 100,000 sq. ft.	1 3					
elec. cranes	.....	5 sheds 6 à 100,000 sq. ft.	2	.....	.....	Both sides	None	.....
hydraulic anes								
lec. crane	.....	.....	.....	.....	.....	.....	.....	980,000 sq. ft.
elec. (3 to tons)	Electric capstans	4 at 80 × 320′ 1 at 80 × 310′ 1 at 80 × 240′	2 decks	.....	(1) 672 (2) 392 (R) 168	60′ between sheds	Private owned in the city also bonded wharves	
elec.	Electric conveyors	5 sheds 80 × 320′	3 at 2 deck					
lec.	telphers, etc.	4 sheds 60 × 320′ 72,650 sq. ft.	1 story					
elec.	telphers, etc.	5 sheds, 60′ × 340′ area 93,420 sq. ft.	1 story					
elec.	2 heavy floating	99′ wide	.....	.....	600			
.....	.....	.....	.....	.....	.....	Boulevard		
ne	None	10 sheds 350 × 100′	.....	.....	?	.....	None	
ne	None	8 sheds	1	?	?	2 × 50′	None	
ne	None	24 sheds 84 × 350′	1 story	?	?	Read 66′ +	None	
ne	None					2 × 50′ and tracks	None	
ne	None							
merous portal gentry anes	Various	16 sheds 110 × 400′	3 and 4 stories					
merous ½ ch cranes	Many land cranes	134′ × 606′ 8″	1	.....	No limit	68′ 9″	4	
.....	.....	134′ × 606′ 8″	1	.....	No limit	68′ 9″	4	78′ 7″ Continuous
merous ½ ch cranes	Many land cranes	216′ 5″ × 606′	1	.....	No limit	75′ 4″	4	
.....	.....	216′ 5″ × 606′	1	.....	.....	75′ 4″	4	65′ 6″ Continuous
12 at 2½ ns	5 hand 6 hydraulic 1 à 150 tons 2 à 50 tons	21 sheds	1 story					
15 à 2½								
13 à 2½	4 floating à 150 tons	20′	.....	.....	.....	Average 69′		

TABLE I.—CHARACTERISTICS AND DIMENSIONS

Location and type	Wharf			Width of apron wharf	Number and location of railroad tracks	
	Length and width in feet and inches	Type of construction	Dock or slip dimensions		Number on apron	Total on wharf
Cape Town						
Table Bay Project						
Two quays	I. 1,400′	.....	Three slips, 500′ wide	.....	2	6
Two quay piers	II. 2,500′	.....	.....	.....	2	6
Casablanca (Morocco)	2 à 380′ × 1,400′					
1919 Quai Paul Chaix	535′ long	Along main Jetty or Mole	.....	49′ 6″	.....	.....
1921 Quai der Phosphates	349′ 6″ long		.....	.....	3	5
1922/24 Quai des Couriers	1,320′ long		.....	.....	.....	.....
Projected I	1,155′ × 528	Bulkhead	577′	.....	.....	.....
	1,155′ × 528	Solid quay pier	.....	.....	.....	.....
II	1,815′	.....	.....	.....	.....	.....
	1,815′ × 528′	Solid quay pier				
(water 31 to 35′) III	2,810′	.....	825′ wide			
	2,640 × 528′					
Genoa (more recent works)						
B Assereto Pier	429 × 1,353′	Solid quay	330′	Ca. 40′?	2	10
Caracciolo Pier	429 × 1,188′	.....	330′	Ca. 40′?	2	10
Victorio Emmanuello III Basin, Middle Pier	429 × 1,221′	.....	.....	.....	2	10
Quay, two sides square	429 × 1,089′	.....	495′	.....	2	4
	429 × 1,386′				2	4
Mari Quay						
Sampierdarena Basin	5,330′	Masonry and fill	1,980′	.....	3	6
Two Branch dock piers (water 45′)	429 × 1,650′	.....	594′	.....	3	12
Gothenberg (Sweden)						
(1892–1902) Masthuggs Quay	3,515′	Masonry wall and fill	River	33 to 46′	Usually 2 each	4
(1910–1917) Stig Bergs Quay	1,681					
(1914) Sannegard Harbour	2,970′	.....	.....	39′ 6″	2	6
(1922) Free Port (water 30′)						
North Pier	2 à 3,745′	.....	Basin 100′ × 2,000′	39′ 6″		
South Pier	26,400′ total quay	Pile, concrete cap and fill		66′	2	4
Hamberg (a few only)						
Sandtor Quay opened 1840 (water ca. 30′) (oldest)	131′ × 3,631′	All works dredged basins (tidal) filled land masonry quay wall	Sandtor Hafen ca. 300′	31′	1	.....
(Longest quay pier) America Quay	4,908′ long	On pile foundation	.....	50′ (?)	1	5
1888–1893 Oswald Quay opened	5,319′ section 416′ wide	.....	.....	50′ (?)	1	
(Newest) Grauenhof Ufer	1,200′	On pile foundation	Kaiser William Hafen average 739′ width	50′	.....	.....
Augusta Victoria Quay	3,578′	.....	.....	50′	2	5
Kronprinz Quay (8 meters water)	3,004′	.....	.....	50′	2	5
Mönkeberg Quay	3,017′	On pile foundation	.....	50′	2	5
Total for Ocean Shipping in 1914 (36′ depth)	158,900′	.....	.....	.....	.....	.....

TYPICAL MODERN MARINE TERMINALS (*Continued*)

Cargo transfer equipment		Transit sheds				Drayway, width in feet	Warehouses	
Main	Auxiliary	Dimensions and area	No. of decks	Heights, areas	Dock loads, lbs. per square foot		Stories, deck loads	Dimensions, length and width
.....	.....	4 each pier 200′ × 600″	1 (?)	.....	.....	.....	None	
elec. steam t 6 tons t 25 tons t 100 tons oating	.....	240,000 sq. ft.	.....	.....	880	.....	.....	Entrepôt under customs
.....	.....	4 à 198 × 561′						
.....	.....	4 à (198 × 561′)						
.....	?							
.....	?	3 à None	?					
.....	.....	132 × 1,485′	..... ?	.....	.....	Wide	Extensive wharf in rear of quay, none back of pier.	
..... à 104 1–5 tons elec.	.....	2	.....	.....	2,650 to 4,000	24′, 9″ 40′	.....	70,000 sq. ft. 79′ and 52′ 9″ wide
l à 22 tons l floating à 80 tons to 5 per berth)	(gantry both sides shed) (one side only)	None	.....	.....	.....	.....	5 4	
.....	.....	7 sheds at 46′ wide length varies	1	.....	.....	.....	6–7 stories stone and brick Typical cross-section Warehouse district Quay 164′ Road 65′ 6″ Warehouse 91′ 8″ Lighter Canal 82′ Warehouse 82′ Quay 137′ 8″	
to 18 à 3 ns for each ed	.....	3 at 165′ × 1090						
.....	.....	2 at 205′ × 1320′						
332 elec. (2 to 3 tons 237 steam à 2½ tons à 50 tons à 75 tons à 150 tons	75 hand cranes à 1 ton	Total length 13,800 m. = 45,550′	.....	.....	.....	.....	Total area 5,003,000 sq. ft.	

TABLE I.—CHARACTERISTICS AND DIMENSIO

Location and type	Wharf			Width of apron wharf	Number and location of railroa tracks	
	Length and width in feet and inches	Type of construction	Dock or slip dimensions		Number on apron	Total on wharf
Hobart, Tasmania						
(1924) Ocean Pier (newest) (water 35 to 60′)	122 × 650′	Open pile	280′ slips	30′	2 each	4
Kobe Japan						
Three double Quay-piers	(1) 180 × 1,290′	Masonry Quay wall and fill	1 à 540′	22′ 6″	1 each wharf	7 each pie
One single (water 30 to 36′)	(2) 366 × 1,248′		2 à 480′			
	(3) 366 × 1,200′					
	(4) 366 × 1,200′					
	Lighter wharf slip bottoms					
Liverpool (example latest works)	210 × 1,270′	Excavated Masonry	Each dock 400′ wide	40′	2	4
	1,300′ 6″				2	8
		Quays and			2	
Gladstone Dock, Branch Docks	300′ × 1,326′ 4″	Wet docks		40′	2	4
(430 acres of docks in addition 27 miles quayage)	260 × 1,115′					
Malmö (Free Port 1922 as example)						
Total length quays, old and new 20,493′	Very irregular	Dug basins masonry quays	Varies	Varies 32′ to 56′		
Total length quays, Free Port 2,282′	(743′) + (1420′)	Dug basin masonry quays	495′ × 1,980′	44′ (13.35 meters)	2	4
Total length, quays Industrial Harbor 2,282	841′ and 1,419′	Depth water 30.8′	330′ × 2,145′			
Rangoon (Burma) 1907						
Sula Pagoda Wharf	1,500′			36′	1	8
Latter Street Wharf	1,300′			36′	1	3
Reval (Esthonia) 1922						
Basin No. 1	2,000′ around basin	Quays Masonry 18′–22′ water	Ca. 226′ wide	SE. side, 55′	2 narrow gage 1 standard gage	3 narro gage 7 standa gage
				NW. side, 40′	1 standard gage	4 standa gage
Basin No. 2	3,100′ around basin	20–24′ deep	Ca. 373′ wide	SE. side, 40′	1 standard	5 standa gage
SE. Victoria and Baykov Quays				NW. side, 50′	1 narrow gage	1 narro gage
NW. Merchants Quay					2 standard gage	2
Basin No. 3	2,680′ around basin	24–30′ deep	Ca. 363′ to 693′ wide	50′	1 standard gage 2 standard gage	3
SE. Merchants Quay					2 standard gage	
NW. Western Mole				45′	1 narrow gage	5
Rouen (France) 1923						
125 kilometers from sea (River and Basins)	25,868′ total quays	16′ 6″→24′ 9″ deep	River	40′ for general cargo	2 to 4	4 to 6

TYPICAL MODERN MARINE TERMINALS (*Continued*)

Cargo transfer equipment		Transit sheds				Drayway, width in feet	Warehouses	
Main	Auxiliary	Dimensions and area	No. of decks	Heights, areas	Deck loads, lbs. per square foot		Stories, deck loads	Dimensions, length and width
ne	None	60 × 650′	1	.....	.....	.....	.....	None
16 tons, 1 5 tons 5 tons, 1 à) tons ch shed's arf cranes	.....	(2) 84 × 360′ 84 × 288′ 84 × 288′ 84 × 285′ (3) 84 × 504′ 84 × 432′ 83 × 288′ 84 × 300′ (4) 6 sheds 84 × 360	1	.....	.....	50′		
at 3 tons at 3 tons at 3 tons at 3 tons	Roadside 17 at 1 ton Hand jiggers 51 inside 49 outside	100 × 1,210′ 100 × 1,280′ 100 × 1,250′ 150 × 1,485′	3	1st, 25′ 2nd, 17′2″ 3rd, 17′2″	1st, 757 2nd, 373 3rd, 311	Ca. 50′ rear all sheds	.....	None
tal 20 light 2 heavy 3 on shed 396′ long	.....	Varies 224′ × 66′ 113′ 6″ × 390′	Treble basement Transit floor Second floor Third floor	8′ 3″ 17′ 13′ 9″ 23′ to ridge	3,960 to 5,500	Rear of shed	Combined wharf and shed Second transit shed	
15 à 3 tons 10 à 35 cantilever hydraulics 2 à 7 tons steam 1 à 30 tons sheer legs	No floating crane	150′ wide 100′ wide	One ?	?	448 Wharf side 896 land side	Rear of shed 280′ for all work 200′	1 group bording wharf 108,000 sq. ft. leased to merchants 1 group 25,000 sq. ft. operated by commissioners (freeport warehouses)	
.....	.....	Southeast side (1) 99 × 330′ (2) 99 × 330′						
.....	2 oil storage tanks and pipe lines							
.....	.....	Northwest side						
.....	.....	Two partition sheds (1) 40 × 412′ (2) 33 × 330′						
lec. at 1½ 3 tons	5 floating à	Vic Shed 36 × 165′ Grain elev. 82′ 6″ × 99′ Shed 36 × 297′						
.....	25 to 60 tons	Byk. wharf 36 × 165′						
lec. à 1½ tons	3 ice breakers	West 99 × 330′ 99 × 660′						
à 1 to 5 ns 10 to 60 floating anes	9 Bridge cranes for coal and other bulk 1 floating 60 tons	50′ sheds 165′ to 85′ wide 222,640 sq. ft. total	1	.....	Ca. 1,200 lb.	Up to 330′ back of sheds for railroad dray	Located near water front several bonded warehouses	

TABLE I.—CHARACTERISTICS AND DIMENSIONS O

Location and type	Wharf			Width of apron wharf	Number and location of railroad tracks	
	Length and width in feet and inches	Type of construction	Dock or slip dimensions		Number on apron	Total on wharf
Rio de Janeiro (Brazil)						
Marginal quay wharf	11,075′	Marginal quay masonry construction, three sections	Ca. 246′	82′	2 double tracks for 1 meter and standard gage	None in rear of sheds
Southampton (England)						
Newest Works, Ocean Dock	200 × 1,592′ 200 × 620′ 200 × 1,595′	Masonry walls quays	1600 × 400′	35′	2 on apron 1 inside	2 in rear 1 inside 6
Total for the Port						
Gold Coast West Africa						
Takoradi Harbor, Lee Breakwater	3,000 × 200′	Breakwater quay	Artificial harbor 330 acres width	40′	2 on apron	4 and lead
Proposed works, Middle Pier.	1,100 × 140′ 3,000 × 550′	Double or quay pier	Between quays 575′	40′	2 on apron	5 per quay
	+625′ connections		25 and 30′ water			10 per pier
AMERICAN EXAMPLES:						
ARNY BASES						
Boston						
Main structure (Quay)	1,638′	Pile apron and fill total width 420′	Wide	34′ 3″ quay side	2	7
Navy pier	924′		35′ M. L. W. 44′ M. H. W.	28′each side	1	5
Open storage	1,000′			420′	2	5
	4,400′					
Brooklyn						
Three to two-deck piers	1,300 × 150′	Pile	Slip 250′	5′ 6″	None	2
Two parallel Warehouses 8 stories						
Charleston						
Bulkhead wharf with 6 right angle adjacent warehouses single stories	Quay 2,160 × 190′	Creosoted pile, apron, concrete cribs and concrete sheet piling with filled land.	30′ M. L. W. 35′ M. H. W. 750′ river channel	40′	1 track 2 crane rails	12 track right ang to trans shed
Newark						
Bulkhead wharf—no transit shed—11 right angle adjacent warehouses	Quay, 3,300′	Creosotedpile and fills	Bassin 400 × 3,800′	80′	3	3 parallel 19 right an
New Orleans						
Bulkhead wharf three right angle six-story warehouses	Quay 2,000 × 170′	Steel-concrete on wooden piles (burned, 400′ rebuilt)	Wide river	20′	None	3 parallel rear
Norfolk						
Two double piers	2 Piers Nos. 1 & 2	Pile	430′ slip	No. 1	36′ 2	No. 1-7
Eight right-angle single stories.	1,328 × 300′	Concrete	35′ M. L. W.		36′ 2	
warehouses		Sheet piles and sand fill	40′ M. H. W.	No. 2	7′ 0	No. 2-5
					36′ 2	

YPICAL MODERN MARINE TERMINALS (*Continued*)

Cargo transfer equipment		Transit sheds				Drayway, width in feet	Warehouses	
Main	Auxiliary	Dimensions and area	No. of decks	Heights, areas	Deck loads, lbs. per square foot		Stories, deck loads	Dimensions, length and width
ny electric rtal cranes	.....	19 sheds at Ca. 125′ + 330′	1	.....	.....	Wide Ca. 135′	Large number (51?) of single-story supporting warehouses to rear of quay sheds	
{ 5 tons and 35 cwt. to each rth) at 2 tons at 3 tons	.....	4 at 120 × Ca. 600′	Single story with passenger galleries	.....	560 lbs.	30′ rear all sheds		
3 at 5 tons 5 at 20 cwt. 7 at 35 cwt. 3 at 50 cwt.	Floating 1 at 150 tons							
.....	.....	4 at 100 × 400′	1	.....	.....	Ca. 35′ between sheds 100′		
.....	.....	1 for manganese in bulk						
.....	.....	8 at 100′ × 350′ to 500′ long	1					
t 3 tons	Cargo masts elevators	1,635 × 100′	2	Areas 318,830 sq. ft.	{ (1) 600 (2) 400	86′	8 floors	1,638 × 126′ 1,651,200 sq. ft.
.....	.....	{ 924 × 100′ 924 × 100′	3	..... 554,000 sq. ft.	{ (1) 600 (2) 500 (3) 300			
signed for idge crane	16 dock winches	.....	.....	88,000 sq. ft.				
rgo masts	90 micro elec. elevators	139 × Ca., 1,300′	2	28′ high	. . . . .	255′ to wharf A	.....	A. 200 × 980′
.....	.....	.....		34′ high		156′ to wharf B	. . . .	B. 240 × 980′
t 15 tons t 25 tons t 40 tons tal electric anes	Cargo masts Shore winches Belt conveyors	(1) 150 × 1,360′ (2) 150 × 400′	1	. . . . .	500	Between warehouses alternating railroad and dray	1 Heavy Area 1,500,000 sq. ft.	6 warehouses at 160 × 1,200′ (16 sections)
ne	None	None 956′ of wharf with light sheds 17 tide ramps for lighters	.....	.....	.....	Alternating between sheds (wharfs)	1	11 at 161 × 1,161′
ne	Cargo masts 5 micro elevators	140 × 2,000′ 10 sections 280,000′ sq. ft.	2	.....	500	Wide levee	3 warehouses 6	140 × 600′ each 504,000 sq. ft. All 1,512,000 sq. ft.
anes but t installed)	Cargo masts Shore winches	No. 1–228 × 1,280′ 2 sheds No. 2 { 2,574 × 1,280′ 257 × 500′	1 1 Except 500′ for troops	.....	1,000 but almost unlimited normal loadings	Alternating railway and drayway 80′ bulkhead open	8 wharfs 1 story	No. 1–2–3 { 160⅓ × 1,400⅔′ 4–5 { 161⅓ × 1,681′ 6–7–8 { 160 × 1,680⅓′

TABLE I.—CHARACTERISTICS AND DIMENSIONS O

Location and type	Wharf			Width of apron wharf	Number and location of railroa tracks	
	Length and width in feet and inches	Type of construction	Dock or slip dimensions		Number on apron	Total on wharf
Philadelphia						
Three deck, double pier	Double pier 1,500 × 290′	Pile and fill	250′	North 35′ So. { 10′ I floor 7′ II floor 7′ III floor	2	4
OTHER RECENT TERMINALS						
Astoria Oregon					10 lines + 11 saw-tooth branches	
Pier No. 1	1,363 × 650′	Pile and fill	400′	None		
Pier No. 2	1,455 × 425′	Pile and fill	350′		8	
Pier No. 3	1,750 × 550′					
Los Angeles						
Double pier	2,400 × 650′	Pile and fill	Wide	20′ 6′ 3″	1 0	9
New Olerans						
Typical river wharf	Marginal pile quay 226′ waters' edge to rear track	Piling for 110′ then fill (levee)	Wide river	15′	0	2 (in rear) 20′ loading platform
Quays on Inner Harbor Canal	265′ wide	75′ concrete slab on piles rest fill		35′	2	4 30′ loadin platform
New York						
Staten Island 10 piers like No. 9,	1,025 × 114′	Wood-piling	300′	5′ 6″	None	None
Two piers like No. 13,	1,030 × 209′	Wood-piling	300′	{ 10′ { 29′	2 2	4
Philadelphia						
Piers No. 3 and 5	500 × 185′	Pile with concrete cap and center fill	250′	2 at 3′	?	
Pier No. 127	626 × 150′			2 at 25′	1 each	2
Pier No. 78	900 × 250′			2 at 20′	1 each	2
Pier No. 84	900 × 300′			2 at 16′	none ?	3
Portland Oregon						
Piers Nos. 2 and 3	1,500 × 450′	Solid fill and pile apron	280′	62′ 6″	2	
Pier No. 4	1,500 × 310′		280′	62′ 6″	2	
Seattle, Wash.						
Smith Cove, B	2,580 × 367′	Pile and fill	Wide		2	8 4 on aprons 4 center (depressed)
Vancouver, B. C.						
Ballentyne Pier	1,206 × 341′	Concrete piles	Wide	?	2 each side	8

PICAL MODERN MARINE TERMINALS (*Continued*)

rgo transfer equipment		Transit sheds				Drayway, width in feet	Warehouses	
Main	Auxiliary	Dimensions and area	No. of decks	Heights, areas	Deck loads, lbs. per square foot		Stories, deck loads	Dimensions, length and width
try and f cranes installed	Microelevators inside	N. 104 × 1,480′ S. { 97′ 6″ / 88′ 9″ / 81′ 9″ } × 1,480	3	(1) 21′ 6″ (2) 12′ 10″ (3) 21′ 4″	500′ 300′ 300′	.....	No other warehouses except 1 story temporary	
....	....	Open Storage 1,550 × 160′	1					
e	Burton masts	2 at 1,800 × 100′	1	.....	?	68′	6′	480 × 152′
e except a n a n a arves	Tractors, conveyors	200′ continuous	1	22′ clear	?	Back of tracks	None	
e	Tractors, conveyors	200′	1	17′ clear	.....	Wide	None	
e à 5 tons ectric)	50-ft. cargo masts Masts	1,010 × 104′ 1,010′ × { 131′ / 116′ }	1 2	23′ { 25′ 6″ / 24′ }	600′ (2)	None	None	
e e e e	None Cargo Masts	..... 600 × 150′ 2 at 900 × 74′ 6″ 2 at 900 × 108″	..... 2 2 2	21′ 6″ and 14′ 6″ 22′ and 16″ 22′ and 14′ 6″	600 and 300′ 800 and 300′ 800 and 300′	Center 61′ Center 68′ railway		
.....	.....	750 × 166′	1	20′				
.....	.....	2 sheds street end 1,000 × 130′	2	?	.....	Wide-center line		
alf-portal e c t r i c nes	4 elec. capstans	3 at 500 × 110′	2	?	.....	Wide middle drive	None	
ns (some used as in conors)	4 elec. elevators 4 elec. escalators	1 at 400 × 110′	.....	(394,000 sq. ft.)				

CHAPTER IV

WHARF DESIGN (*Continued*)

STRUCTURAL CONSIDERATIONS

1. PILING

Advantages of Wooden Pile Construction.—Pile construction, where the marine borers are not present, in water full of sewage in fresh water and in northern waters, is remarkably permanent. Wooden piles when constantly submerged are practically immune to decay. This condition may be maintained to a height of the mean between high and low tide. Up to that point it is possible for the pile to remain always wet. Air, heat, and moisture are necessary for the decay of the wood. Where the air is shut out by water, the decay is very slow.

Pile construction has several advantages other than simple cheapness.

1. A pile structure does not materially reduce the tidal prism. That is, it does not affect materially the amount of water which flows through its channels into and out of the harbor with the changes of tide.[1]

2. Pile wharves are more elastic. The kinetic energy of a ship moving at a speed of 1 mile an hour or 1½ feet per second is 350 foot-tons and twice this speed 1,500 foot-tons.[2] This energy must be absorbed in some manner or it acts as a destructive force of that amount to both pier and ship. Ships will shun a wharf that puts all the destructive force of impact on the ship. An elastic pile structure absorbs this energy. With other kinds of solid structure fenders must be provided, such as buffers made of faggots, rope, or timber and springs.

As piles below the water line are practically immune to decay the more recent practice has been to cut off the piles at low water and cap them with concrete.

There have been many failures of concrete in subaqueous construction. It has been found that when concrete has been cast on shore and allowed to harden or set before coming into contact with the water this concrete has held. The latest form of concrete cap to pile structures as developed at the Brooklyn Navy Yard and adopted at some of the Barge Canal terminals takes this fact into account. Reinforced concrete columns in "T" form, with the iron rods projecting from the arms of the "T" in hooks, are cast on shore and allowed to set. The piles are cut off a little above low water and the set "T" fastened onto the ends of the piles,

[1] See "Port Development," Chap. VIII, on Tides, p. 165.

[2] Greene, Carleton, "Wharves and Piers."

usually to pile clusters. The "T" arms are then connected and formed into the regular reinforced concrete beams by the usual method of casting on the job. A concrete floor or pier deck is laid over this and faced with 1½-inch asphalt to give a better wearing surface. The life of these piers will be followed with interest as time passes.

The pile construction has become more difficult and expensive owing to the lack of good piling. The all-water-via-Panama-Canal-route will make Douglas fir in 120-foot lengths available on the Atlantic coast. This is the best timber for such construction.

The depth of water must be considered where piles are used. Where the depth of water does not exceed 25 feet, the bearing power of 14- to 16-inch wooden piling is 12 to 15 tons. Piles should be cross-braced as far down as possible. A draw-back to the use of concrete piles is the difficulty of cross-bracing. The deflection of an unbraced pile is that of a cantilever beam and varies as the cube of its unsupported length.

In mud bottom the bearing power of a pile foundation is obtained by finding the skin friction of test piles. The kind of bottom available is most important in the choice of the entire layout, even to the size of the pier and the freight handling installations it will carry.

3. The third chief advantage of pile structures is cheapness and rapidity of construction as compared with filled structures which require considerable time to settle.

Life of Structure and Obsolescence.—From the viewpoint of financial efficiency, cheapness of construction as well as speed of construction is important. In every commercial center there are unforeseen events which may lead to a complete change of conditions. It is therefore seldom advisable to make the total first cost very large by installing works with a longer life than half a century, or even 25 years. In European ports where the entire port is a municipal or government institution, harbor works have been built to last centuries. There is no doubt that they are cheaper in the long run, and require smaller annual amortization and depreciation than a pile structure, because the period of amortization is longer and the structure more durable. That is, if the life of the installation is calculated for over 50 years the depreciation will be 2 per cent per annum. If the life of the pier is calculated for 25 years the depreciation is 4 per cent. The annual percentage of income from the pier which must be written off as the replacement of capital is twice as large in the case of a 25-year structure as against one with 50 or more years of life. However, if the original investment of the pile structure with its light superstructure is only half that of the expensive wall-and-fill, then the actual annual replacement fund in cash is the same amount in both cases, 2 per cent of $1,000,000 for 50 years, or 4 per cent of $500,000 for 25 years.

The difference comes in *the degree of obsolescence* at the expiration of the 25- or the 50-year period. It is not always possible to calculate in

advance the changes in the size of ships and the methods or location of doing business which may take place during the years of the life of the pier. In American ports at the present time, all prophecy is hazardous and a pier with a long life and high initial cost may become obsolete long before it has paid for itself. However, questions of maintenance and operation are more important than obsolescence. Some considerations of types of construction from this angle are maintained at the close of this chapter under Sec. 5.

For both marginal wharves and piers there are two types of construction, *the pile structure* and *the solid fill*. In most cases the cheapest form of construction is the wooden pile. Pile structures may carry greater weight than filled structures when the bottom is of loose mud. With a loose mud bottom the filling acts only as an additional load and is a detriment rather than an advantage.

Where the wharf is wider than 250 feet the filled structure is more economical and, if the bottom warrants it, more permanent. Where the water is infested by teredo, limnoria, and other marine borers, the solid fill becomes almost a necessity. It is possible to encase the piles in a concrete shell. Creosoting is little protection against the destructive animals because they usually find some avenue of entry. The filled structure with only the outside rows exposed and accessible for renewal is necessary. This construction is possible at low cost where the slip dredgings may be used for the purpose.

2. MARINE BORERS

Marine borers are worms that eat into and destroy wood submerged in salt or brackish water. They have been known since early history.[1]

The families are divided into *mollusca* and *crustacea*. Oysters and clams are typical of the mollusca, while the family of crustacea is represented by lobsters, crabs, etc.

The *mollusca* consists of two groups, the *teredo navalis* and the *xylotria*. These bore into the wood, making long tunnels and weakening the piling or ship's timbers.

In the *crustacea* group we find the *limnoria*, the *sphaeroma*, *the chelura* and others, which chew the wood, forming shallow burrows, resulting in the hour-glass form, and the eventual cutting of the pile in two (Fig. 32).

Characteristic of the *teredo* group of the mollusca is a long worm-like creature, which bores into the wood head foremost, drilling its way by means of two small shells, which form part of the head, for excavating, as it were. The bodies of the borers vary in size, from the length and thickness of a lead pencil to 1 and 1½ feet in length. There may be 50,000 to 100,000 in one pile. They work so rapidly that a Douglas fir pile, 2 feet in diameter, was destroyed in less that 6 months.

[1] VON SCHRENK, HERMAN, Timber Engineer, in *World Ports*.

Various types of borers and ship worms adapt themselves to various degrees of salinity. They are distributed from the equator to the Arctic Circle. Temperature changes have little influence over their distribution. However, waters in which the quantity of oxygen is low will be free from these organisms. High sewage pollution making water unfit for their life render a harbor immune, but the recent appearance of marine borers in San Francisco Bay waters, and even in the waters of New York Bay, indicates that this is not always the case.

The *limnoria*, also known as the *boring gribble*, is found on all our coasts. It looks something like a grain of rice with a body containing fourteen segments with stout legs and lobster claws.

(*Photograph by the author.*)

FIG. 32.—Going, Going, Gone! Limnoria and Teredo depredations on the piling of the Carolina Yacht Club, Charleston, S. C., exposed at low tide. The wharf is almost completely destroyed, although sufficient new piles have been driven to maintain a factor of safety ample for its uses.

Considering the occurrence of all types of borers, very little is known about them. They appear on the various sea coasts of the world. A joint committee of the Danish, Swedish, and Norwegian Engineering Societies has made a study of maps indicating the appearance of teredo and limnoria in northern Europe. The sudden appearance in San Francisco Bay, which had been quite free from marine borers, of the typical Holland ship worm, or *limnoria*, was a great surprise. It destroyed twenty million dollars' worth of property there. An investigation was made and report submitted by the San Francisco Bay Marine Piling Committee.[1] The study of marine borers has since been undertaken on a national scale by the National Research Council.[2]

[1] To the American Wood Preservers Association, 17th Annual Meeting, 1921, pp. 189–339.

[2] *Marine Piling Investigations*, published by the National Research Council, 1924, pp. 534.

Concrete Marine Borers.—Often concrete is not immune to the attack of rock-boring mollusca of the family *pholadidae*. These enemies seem to be distributed in several species from San Diego to Alaska. They were first discovered in Los Angeles harbor in 1922.

These borers are generally a little larger than a man's thumb. The largest one found occupied a burrow measuring 1⅜ inches in diameter. Two borers in this jacket had penetrated the concrete until they came in contact with the wood within, but none had actually bored into the wood.[1] The species occasioning most of the damage was found to be *pholadidae penita conrad*, known commonly as the *rock clam*. It occurred from 2 feet above mean low water to 1 foot below, which was the lowest we were able to work. It doubtless similarly occurs on down to the mud, even in deep water, as it has been dredged in San Francisco Bay at a depth of 50 fathoms.

Another boring species found in concrete pile jacks here was *platyodon cancellate conrad*, a near relative to the soft-shelled clam (*mya arenaris*). This form inhabits normally stiff mud and clay. It was found in the pile jackets only sparsely, and in decidedly poor concrete.

A third species occurring in the concrete jackets was the so-called *nestler petricola carditoides conrad*, which is believed not to bore on its own account, but only to inhabit natural cavities, or holes, bored by other organisms.

The finding of destructive marine borers in concrete is not encouraging to most engineers who consider concrete a permanent subaqueous foundation.

The protection against wood borers is found in concrete. Timber piles are made teredo resistant by creosoting; however, unless the creosoting is thoroughly done and no injury occurs to the pile to break the creosoted outer surface below the point of penetration of the creosote, the borers will find entrance and destroy the pile from the inside.

The standard specifications for creosoted piling are as follows:

Materials:

I. Piles

1. Piles shall be unhewn yellow pine.

2. For lengths not exceeding 30 feet, the minimum diameter at the tip shall be 9 inches. For lengths over 30 feet, but not exceeding 50 feet, the minimum diameter at the tip shall be 8 inches. For lengths exceeding 50 feet the minimum diameter at the tip shall be 7 inches. The minimum diameter one-quarter of the length from the butts shall be 12 inches, and the maximum diameter at the butt shall be 20 inches.

3. Piles shall be butt cut above the ground swell, have a uniform taper from butt to tip, shall be free from short bends, and so straight that a straight line from center of butt to center of tip shall lie within the body of the pile. When cut, they shall be peeled and shall have the inner skin or bark completely removed. They shall not be allowed to lie on the ground, but if not moved at once to the treating plant they shall be placed on skids. All knots and scars shall be trimmed close to the body of the pile, so that when it enters the cylinder its surface shall be smooth.

[1] "The Service Bureau, American Wood Preservers Association," in *World Ports*, 1923.

4. Piles shall be sound and free from the following defects: large, loose, unsound or hollow knots; worm holes; knot holes; round shakes; red heart; or other defects which will impair their strength or durability. Turpentine faces not over 2 feet in length will be allowed, provided they do not materially reduce in size.

5. Piles shall have a sap ring of not less than 3 inches nor more than 5 inches.

6. Piles shall preferably be treated green, not later than 2 months after cutting. If partly seasoned piles are accepted for treatment, they shall receive same treatment as green piles.

II. Timbers

1. Timbers shall be southern yellow pine.

2. Except as noted, timbers shall be sawed to standard size, full length, square cornered, and straight; close grained and free from defects, such as injurious wind shakes and cross-grain, unsound or loose knots, knots in groups, decay, or other defects that will materially impair its strength.

3. Timbers shall be sound, sap no objection. Wane may be allowed one-eighth of the width of the piece measured across the face of the wane, and extending one-fourth the length of the piece on one corner, or its equivalent on two or more corners, provided that not more than 10 per cent of the pieces of any one size shall show such wane.

4. The bark and inner skin shall be completely removed from the wane.

III. Oil

1. Oil shall meet A. R. E. A. Standard Specifications for Creosote Oil. It shall be analyzed when received at the works in accordance with the recommended practices. See item 20.

Treatment:

1. The treating plant and all equipment shall be maintained in first-class condition satisfactory to the Inspector throughout the treatment.

2. Cylinders shall be supplied with air vents, steam coils; with recording gages and thermometers, necessary to record the condition at all times.

3. The owner of the plant shall provide and keep in condition for use at all times the apparatus and chemicals necessary for making the analyses and tests required by the specifications.

4. Each charge shall include only piles of approximately equal sap wood content and equal seasoning.

5. After placing in the cylinder, piles or timbers shall be steamed at least 20 hours. The temperature shall be gradually raised to 280° F. (138° C.) in 3 hours, held at this temperature for 8 hours and gradually lowered to 250° F. (121° C.) at the end of the steaming period. The cylinder shall be frequently drained of condensation. The steam shall then be blown off. A vacuum of at least 24 inches shall be created in ½ hour and held at least 24 inches for a period of at least 5 hours. Oil shall be introduced without breaking vacuum until the cylinder is filled. Pressure shall be applied gradually, and maintained until sufficient oil has been injected to leave the required amount in the piles after releasing, or until in the judgment of the inspector the refusal point has been reached. The pressure shall not exceed at any time 200 pounds per square inch. The temperature of the oil during the pressure period shall not be less than 170° F. (77° C.) nor more than 200° F. (93° C.) and shall average at least 180° F. (82° C.).

6. After treatment has been completed and the oil has been removed from the cylinder, the piles or timber shall be allowed to drain ½ hour.

7. Unless the oil has been injected to refusal, at least 22 pounds per cubic foot shall be retained in the piles.

8. All measurements of oil shall be based on a temperature of 100° F. (38° C.) and correction shall be made for actual temperature by applying a proper reduction factor.

9. Oil from each charge shall be analyzed for water content. No oil containing more than 3 per cent of water shall be used.

10. Vacuum measurements specified herein are for treating plants located at the sea level. If plant is not located at sea level, proper correction for altitude shall be made.

11. At least three piles in each tram shall be bored to test penetration of oil, and record shall be kept by inspector.

12. Hole for testing shall be bored about 6 feet from butt and plugged by a round creosoted plug, $\frac{1}{16}$ inch larger than the hole.

Recommendations for Handling and Installation:

1. Do not use cant hooks or dogs in handling. Use rope slings.

2. Do not drop the piles when unloading so as to crack them or injure them.

3. Frame and bore all timbers before treatment, whenever practicable.

4. Whenever it is necessary to cut the piles, or timbers, or whenever they become scarred or abraded, carefully trim the abrasions and coat the cut surfaces with hot creosote oil and cover with roofing pitch.

5. Bore bolt holes $\frac{1}{16}$ inch smaller than the bolt and pour in hot creosote oil before driving bolts.

6. Pour hot creosote oil into all unfilled holes and plug with treated plugs.

7. Particularly avoid cutting or boring below high water mark.

8. Drive piles as soon as possible after treatment. If necessary to store them cover with earth to prevent checking.

9. These particular marine borers live and breed in wood exclusively. It is, therefore, probable that a great deal can be accomplished in checking their attacks by destroying their breeding places. It is recommended that all unused or untreated piles or timber be removed from the water in the vicinity.

10. The purpose of the heavy treatment and care in handling recommended here is, first of all, to prevent the borers from gaining foothold, and, therefore, really applies only to that part of the pile between high water mark and the mud line.

A Quick Test of Cresoting.—Some contractors make a quick test of the degree of cresote penetration by dropping the piles into the water and accepting those that sink and refusing those that float. A rope cradle alongside car trestle or lighter is made to catch the piles, at a shallow depth.

An interesting table concerning the life of creosoted Douglas fir piling at San Francisco Bay is reprinted here:[1] (Table II, pp. 70 and 71.)

Comparative Costs of Piling.—In view of the dangers of destruction or deterioration of various types of pile wharf structures, first costs and maintenance must be considered together, in conjunction with such other items as years of service expected and obsolescence. Costs rest upon so many variables that it is almost impossible to attempt even an approximation in a work of this sort. F. G. White[2] of San Francisco, however,

[1] Hicks, P. R., in *World Ports.*

[2] White, F. G., Chief Engineer, California State Board of Harbor Commissioners. "Timber *vs.* Concrete for Construction of Port Terminal Facilities," paper before the Pacific Coast Association of Port Authorities, Seattle, Sept. 3, 1924, also in *Ports and Waterways* and in *World Ports*, January 1925 and February 1925.

has recently compiled some standard figures of construction costs by assuming several variables at stated known quantities. This is a real contribution and a summary of these findings is quoted as the best guide posts to date.

Construction costs are so materially affected by varying physical conditions and costs of labor and material, that a comparison of different types of construction is impossible without making very definite assumptions regarding these factors. For the purpose of simplifying this comparison it is assumed that the structure to be analyzed is a simple pier approximately 100 feet in width, designed for a live loading of 500 pounds per square foot. The costs include allowances for the necessary brace piling but do not include fender lines, railroad track or building supports, deck paving, mooring bitts, or other pier accessories. Costs are tabulated for three lengths of pile supports: 50 feet, 75 feet, and 100 feet. Stress assumptions for timber, steel, and concrete are in accordance with the standards of the Board of State Harbor Commissioners of San Francisco. The bearing capacity for timber piles is assumed at 27½ tons and for concrete piles 40 tons. Creosote treatment is standard 12- and 6-pound treatment for piles and timber, respectively. Concrete in piles, jackets, and deck is proportioned 1 part cement to 5 parts selected aggregate.

Cost assumptions are as follows: untreated timber, $30 per thousand; creosoted timber, $70 per thousand; untreated piles 22 cents per lineal foot; creosoted piles, 68 to 75 cents per lineal foot; cement, $2.75 per barrel; concrete aggregate, $2.25 per cubic yard; reinforcing steel in place, $70 per ton; pile driver and carpenter labor, $8 per day; concrete labor, $5 to $5.50 per day; pile coating, 60 cents per lineal foot of coating; concrete jacketing of piles, $2.75 per lineal foot of jacket. The costs as tabulated include allowances for plant, overhead, and contractor's profit.

Cost per Square Foot of Floor Area

Type of structure	50-ft. pile	75-ft. pile	100-ft. pile
Untreated piling and untreated timber deck	$0.77	$0.87	$0.97
Coated pile with 25-ft. protection and untreated timber deck	1.03	1.13	1.22
Coated pile with 40-ft. protection and untreated timber deck	1.18	1.28	1.38
Creosoted pile and untreated timber deck	1.17	1.47	1.78
Creosoted pile and treated stringers and caps	1.54	1.84	2.15
Concrete jacketed pile with 25-ft. protection and untreated timber deck	1.73	1.82	1.91
Concrete jacketed pile with 25-ft. protection and reinforced concrete deck	1.95	2.05	2.14
Concrete jacketed pile with 40-ft. protection and reinforced concrete deck	2.59	2.69	2.78
Reinforced concrete pile and reinforced concrete deck	1.97	2.65	3.70
Concrete cylinder and reinforced concrete deck	4.48	5.70	6.40

TABLE II.—DATA ON THE LIFE OF CREOSOTED DOUGLAS FIR PILING IN SAN FRANCISCO BAY[1]

Number and character of piles	Location	Installed by	Date installed	Date removed	Length of service, years	Condition	Remarks
754 bearing and fender piles	Ferry Slip, foot of Broadway, Oakland.	Southern Pacific Company	1898	Still in service	22	Bearing piles in good condition, spring line piles where damaged mechanically attacked by limnoria.	No bearing piles removed. Fender piles replaced as damage necessitated repairs.
4,500 bearing and fender piles	Ferry Slip and marine ways, foot of Peralta St., Oakland.	Southern Pacific Company	1896 to 1902	Still in service	18 to 24	Bearing piles in good condition, spring line piles where damaged mechanically attacked by limnoria.	No bearing piles removed. Fender piles replaced as damage necessitated repairs.
1,491 bearing and fender piles	S. P. Ferry Slip, Alameda Mole.	Southern Pacific Company	1902	Still in service	18	Bearing piles in good condition, spring line piles where damaged mechanically attacked by limnoria.	No bearing piles removed. Fender piles replaced as damage necessitated repairs.
1,391 bearing and fender piles	S. P. Freight Slip near Oakland Pier.	Southern Pacific Company	1903 to 1904	Still in service	16 to 17	Bearing piles in good condition, spring line piles where damaged mechanically attacked by limnoria.	No bearing piles removed. Fender piles replaced as damage necessitated repairs.
2,880 bearing and fender piles	S. P. Ferry Slip, Oakland Pier.	Southern Pacific Company	1898	Still in service	22	Bearing piles in good condition, spring line piles where damaged mechanically attacked by limnoria.	No bearing piles removed. Fender piles replaced as damage necessitated repairs.
14,000 bearing and fender piles	S. P. Long Wharf, Oakland.	Southern Pacific Company	1890 to 1901	1918 & 1919	18 to 29	74.7 per cent fit to redrive when structure was removed.	No bearing piles removed. Fender piles replaced as damage necessitated repairs.
1,264 bearing and fender piles	S. P. Freight Slip, Mission Bay, S. F.	Southern Pacific Company	1904	Still in service	16	Bearing piles in good condition, spring line piles where damaged mechanically attacked by limnoria.	No bearing piles removed. Fender piles replaced as damage necessitated repairs.

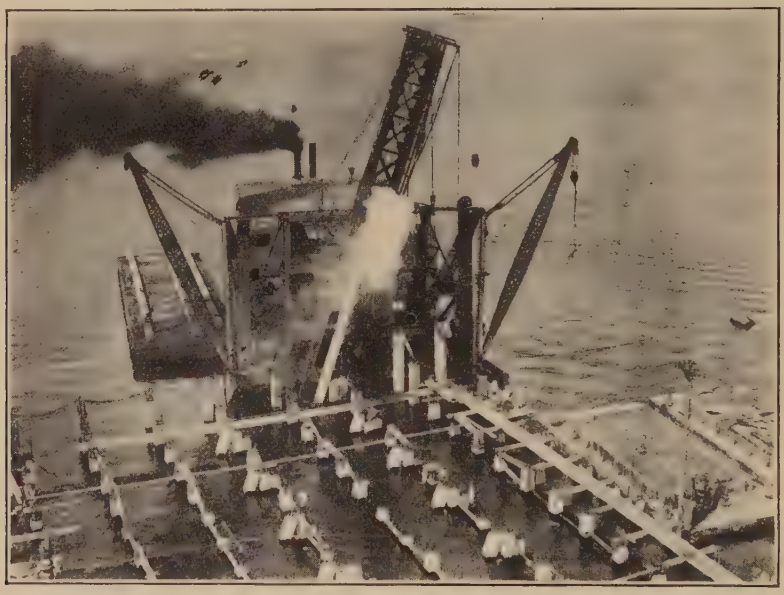
2,562 bearing and fender piles	S. P. Trestle at Dumbarton Cut-off.	Southern Pacific Company	1907 to 1910	Still in service	10 to 13	21 per cent attacked by limnoria due to defective treatment and abuse in handling.	Bracing placed below high water, and limnoria have entered around bolt holes.
521 bearing 379 fender — 900	Pier 36, San Francisco	State Board of Harbor Commissioners	1909	Still in service	11	17 found badly attacked by limnoria at about low water.	Rowboat inspection at low tide.
36 bearing	Pier 20, San Francisco	State Board of Harbor Commissioners	1912	Still in service	8	Good above low water.	Rowboat inspection at low tide.
1,355 bearing 418 fender — 1,773	Pier 16, San Francisco	State Board of Harbor Commissioners	1915	Still in service	5	About 5 per cent damaged by limnoria between high and low water.	Ditto. Damage is in dog holes or other places where treatment is cut or broken.
1,355 bearing 418 fender — 1,773	Pier 18, San Francisco	State Board of Harbor Commissioners	1915	Still in service	5	About 5 per cent damaged by limnoria between high and low water.	Ditto. Damage is in dog holes or other places where treatment is cut or broken.
102 bearing 20 fender — 122	Pier 20, San Francisco	State Board of Harbor Commissioners	1915	Still in service	5	Good above low water except in a few dog holes.	Rowboat inspection.
293 bearing 377 fender — 1,670	Pier 15, San Francisco	State Board of Harbor Commissioners	1914	Still in service	6	Good above low water except in a few dog holes.	Rowboat inspection.
503 bearing	Pier 19, San Francisco	State Board of Harbor Commissioners	1914	Still in service	6	Good above low water except in a few dog holes.	Rowboat inspection.

[1] Also see "Marine Piling Investigations," National Research Council, Washington, D. C., 1925. 534 pp.

In the case of the concrete cylinders the last item of cost is based on a 75-foot cylinder resting on a cluster of piles driven below the mud line.

The cost of maintenance and the probable length of life of structures of the different types are quite as important as the original cost of construction. They are, however, more difficult of determination and it is possible at this time to present only very general statements regarding these points.

Recently, Raymond G. Osborne invented the asphaltum piling, a concrete pile treated with asphalt for which is claimed that it protects it against all action of salt water or the elements. The Los Angeles Harbor



(*Courtesy of E. Clinton Earle, Manila.*)

FIG. 33.—World's largest pile driver, (?) "Mammoth." Driving piles 110 feet long, Pier 7, Manila.

Department has recently awarded a $170,000 contract for the construction and driving of 40,000 feet of the new piling, so successful has been its experimental use.

The Osborne asphaltum piling is poured in an ordinary form and allowed to stand for 30 days, when it is removed, unusually porous and rough appearing. It is then placed in a boiling vat of asphalt, the final treatment.

From 240° F. the temperature of the asphalt is increased until it reaches 500°, after which it cools gradually. The asphalt permeates he concrete piling and also gives the outside of the column a protective coat which engineers say will make it last for a century.

Concrete Jacket on Untreated Piles.—A new method of protecting piles in worm-infested waters has been used in new wharf con-

struction at San Francisco by F. G. White. This consists of a precast reinforced concrete jacket around an untreated wooden pile sunk to well below the mud level. The precast jackets are jetted

(*Photograph by the author.*)

FIG. 34.—Precast concrete jackets to encase untreated wooden piles at San Francisco (1925).

down. The pile is then driven inside the jacket to refusal. In driving the pile, a water gasket consisting of an old automobile tire is put around the pile. As the pile goes down this rubber is carried

(*Photograph by the author.*)

FIG. 35.—Precast concrete jackets to encase untreated wooden piles at San Francisco. Piles driven inside the jacket, grouted and cut off at level.

with it and squeezes all the mud and water out of the jacket. The space left between pile and jacket is then grouted, filled with concrete, making a solid concrete pile with a wooden core. The jacket is

designed strong enough to carry the load alone if the piling should be destroyed from within. The economy is doubtful. At the shore end of the pier where the exposed portion of the pile is short, therefore requiring a short jacket, the saving by not creosoting offsets the cost of the concrete jacket. However as the water depth and jacket length increase the cost of the jacket increases to a point beyond which there is increased cost over straight concrete piles. The method is ingenious and should show great strength and permanency. It is an interesting experiment in a highly experimental field. (Figs. 33, 34).

New Works at Vancouver, B. C., Manila, P. I., etc. now under construction have been using reenforced concrete piles, up to 110 ft. in length. When driven to refusal the job of cutting off is difficult. This is the case of the new C.P.R. pier at Vancouver.

Some of the longest concrete piles noted to date, 110 feet long with a 24- by 24-in. cross-section, were used by E. Clinton Earle in the new pier No. 7 at Manila, P. I.

3. QUAY WALLS

Sheet Piling, Bulkheads, and Revetments.—The question of obsolescence has less bearing in the case of bulkheads than in the construction of narrow piers. The bulkhead line generally is a fixed one, and the bulkhead itself is a retaining wall for the solid fill behind it. It is practically certain that the bulkhead will not be changed in the course of a great many years, although piers, with slips between them, are designed with practically no margin for expansion and in the last 50 years soon became antiquated. The bulkhead—quay type of wharf construction—has an advantage over piers and slips with respect to obsolescence, providing there are few angles or bends in the wall. The universality and flexibility of accommodation at quays is nullified by frequent angles or breaks in the wharf frontage. Also quays are designed with such ample dimensions that the growth of ships from 30 to 100 feet beam or from 350 to 1,000 feet in length will cause no material increase in the congestion of slip or quay. The bulkhead, once established, will remain when small pile piers may be ripped out later to accommodate increasing vessel dimensions.

There are some recent examples of permanent construction of bulkhead walls, such as the two great piers of the Army Supply Base at Norfolk, in the quay basin type of European port expansion, and in the retaining walls of the basins of the New York State Barge Canal terminals, where these assume the marginal form of development.

There are two principal types of sheet piling used in this country to retain the earth fills either in bulkheads or large piers of the quay type. For rapid work of a limited life, steel sheet piling, with interlocking edges, is popular. This form is found frequently in the construction of cofferdams. For permanent jobs concrete sheet piling with mortise and tenon

interlocking joints has been successful. A typical example is both the bulkhead and the pier sheet piling at the Norfolk Army Supply Base. These piles were 18 by 24 inches in size, of reinforced concrete, cast on shore, and air cured for 30 days before setting. As concrete piles are difficult to drive without shattering the material, the center of the pile carries an iron pipe extending the length of the pile. To this is attached a powerful water pump, when the piles are sunk. The water jet forces the material away from the foot of the pile permitting the pile to sink to its position with very little force except agitation and its own weight. This setting of concrete piles by means of a water jet has become standard practice in soft or sandy subsoil.

Test Boring.—It is, of course, understood that test borings are taken of the area in which work is contemplated before the structural design of the work is undertaken, in fact, before estimates of cost can properly be made.

Leaky Bulkheads.—Sheet piling, with its interlocking mortise and tenon, must be tight to prevent leakage. If land is being retained behind the bulkhead by hydraulic dredge, much of it will wash out through leaks in the sheet piling wall unless great care is taken to make this wall tight. Also, after the structure is finished, the wave action from without and seepage from within will wash the fill through the piling into the channel and destroy the structure if walls are not properly tight. This "caulking" of sheet pile construction is done by forcing down either liquid or small bag concrete. This is called grouting.

All sheet piling is tied back by stringers and anchor piles to withstand the outward thrust of the fill. Anchor piles are also called bollards, "dead men," horizontal girders, upset bars, tie backs, etc.

Concrete Piles.—The driving of 250-foot piles for the Hudson River tunnel shaft presents some very interesting problems. There are 42 piles or columns of reinforced concrete extending from ledge rock to the bottoms of each of the ventilating shafts. The weight on each pile of these shafts is estimated at 97 tons and designed with a maximum bearing of 126 tons per pile. These reinforced concrete piles are 24 inches in diameter. Because of the supporting earth in which the columns are driven, bending stresses with regard to their characteristics as to columns were not considered. Pipes similar to oil well drilling were sunk in sections, as sinking piles of 250-feet length by the usual water-jet method would not insure their remaining plumb. The hole was drilled in advance of the pile by a bit operated through the center of the pile. In this manner, the piles were both drilled and hammered, light tapping often being sufficient. This drilling of a hole to receive the pile by a bit is called *spudding*. After the pile had reached its seat the hollow portion was filled with concrete.[1]

[1] A full description is given in *Eng. News*, Vol. 90, No. 6, p. 242, Feb. 8, 1923.

Quay-wall Design.—Quay walls of concrete or granite and concrete, mounted on piles, are the usual method of structure in European harbors. As in concrete-capped, open-pile piers, the presence in the harbor waters

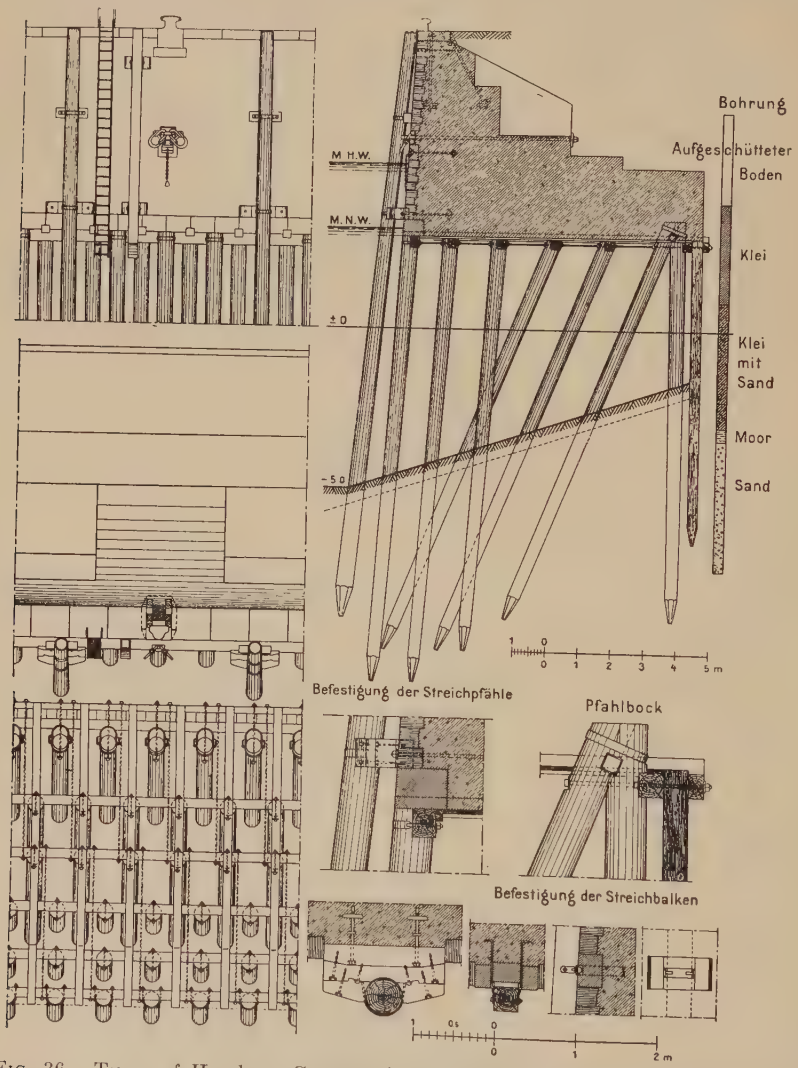
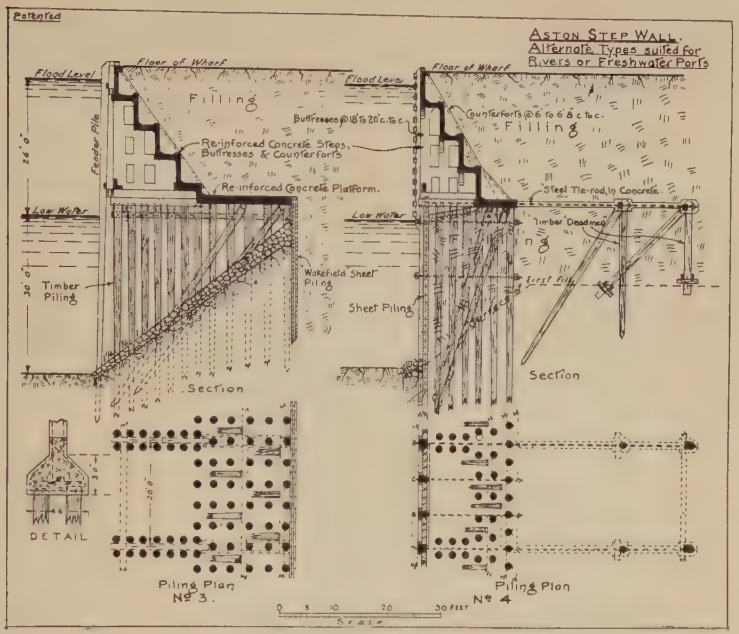


Fig. 36.—Types of Hamburg Construction. Hamburg quay wall on Stettin Quay. The Hamburg harbor is free from marine borers. Shows plan and section, also test boring and method of securing fender piles (Streichpfäle)—scales all in meters. Depth nearly 40 feet at high water.

of the ship worm (teredo, limnoria, etc.) will usually preclude a wooden pile foundation for quay walls and make some form of stone or concrete base necessary. Complete details of a typical Hamburg[1] quay wall are

[1] Fresh water.



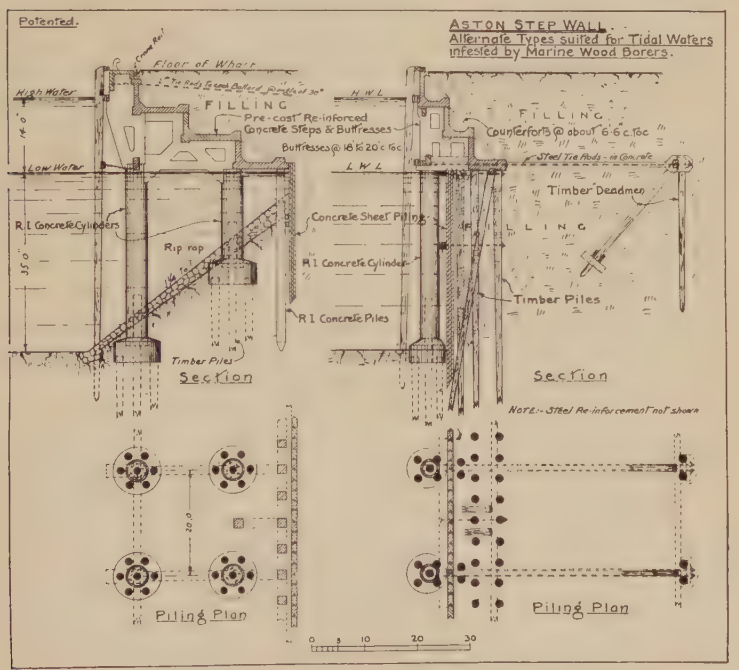


FIG. 37.—Aston patented quay walls for fresh and tidal water conditions.

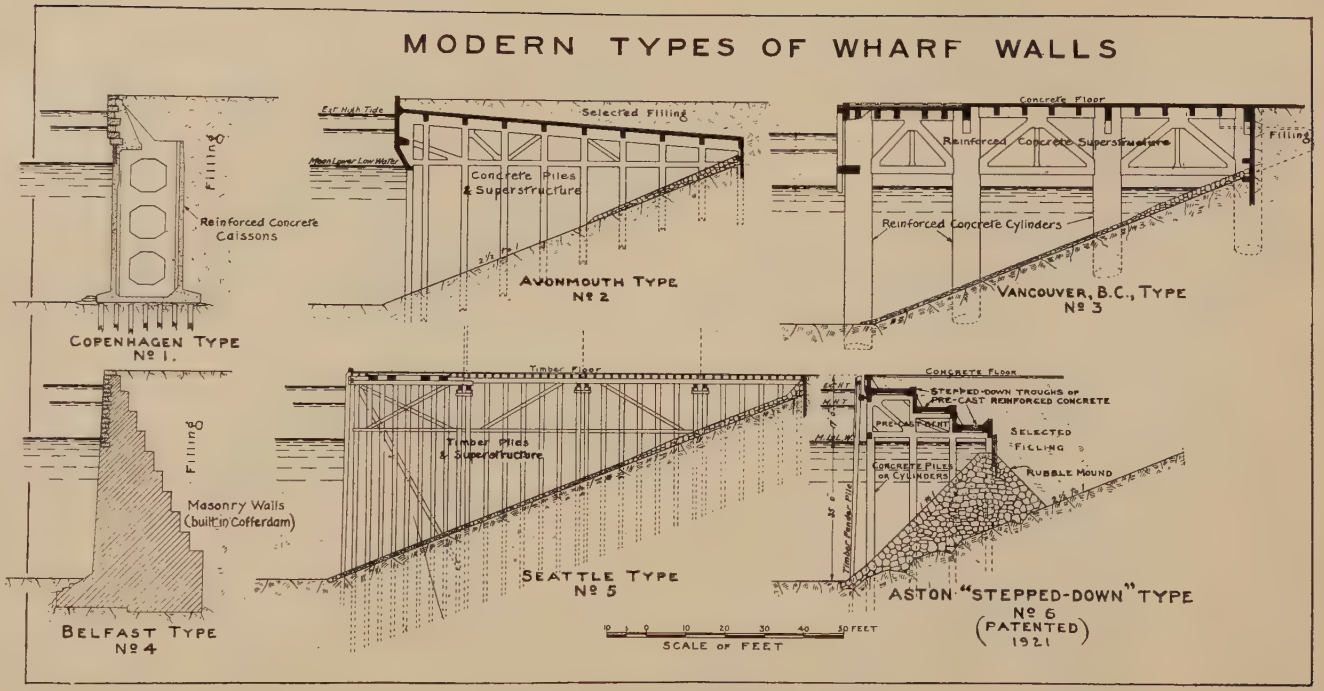


FIG. 38.—Cross-sections of wharf walls are drawn to a uniform scale, tidal range, dredged slope, and conditions in order to furnish a fair comparison as to magnitude and cost.

given in the accompanying illustration (Fig. 36). In fresh water (or brackish) piles permanently submerged are immune to decay. However, with marine borers present another system must be followed.

Aston Patented Quay Walls for Fresh and Tidal Waters.—Figures 37 and 38 show some American examples of quay wall designed for both conditions. Approximate costs under Pacific coast conditions are also appended as a basis for comparison.

Fresh Water (Fig. 37) Nos. 3 and 4.—As the timber which is shown below the concrete wall would be wet at all times, it would be proof against "dry-rot," and also fireproof—thus being as permanent as the concrete superstructure. In Type No. 3, the lowest relieving platform might be of timber where continually kept wet. "Dry-rot" does not affect timbers up to 2½ feet above low water.

Approximate Cost, per Foot Run, of Wall Type No. 4

(Pacific Coast unit prices, 1923)

2.3 cubic yards concrete, including forms, at $19	$43.70
208 pounds steel reinforcement, at 5½ cents	11.44
580 board measure feet 18 inch square timber piles, and 12 inch sheet piling, at $50	29.00
170 board measure feet timber fenders, beams, etc., at $36 per thousand	6.12
78 lineal feet timber piles, untreated, at 28 cents	21.84
94 pounds steel in tie rods, washers, etc., at 7 cents	6.58
1.2 cubic yard riprap at $3	3.60
Contingencies, royalty, and engineering	24.46
Cost per foot run of wall	$146.74

Note: Filling not included.

For Worm Infested Water.—In long spans, or widths, of flooring of steps, the under surface might be ribbed or arched so as to place it in compression, and thus eliminate hair cracks. The vertical and horizontal walls of the top steps are from 7 to 8 inches thick, increasing in thickness in steps below; shear governing in designing steel for vertical walls, which act as girders.

The thickness of sheet piling will be governed by the depth of water and nature of the material to be retained. A large safety factor should be used in designing the tie rods and "deadmen." In Type No. 2 the timber piles, being surrounded by filling, are immune from marine wood borers. They are also immune from "dry-rot" as they are placed below low water.

Approximate Cost, per Foot Run, of Wall Type No. 2

(Unit prices are those prevailing in 1923 at Portland, Ore., and Vancouver, B. C.)

4.33 cubic yards reinforced concrete in steps, bents, counterforts, cylinders, and sheet piling at $26 per cubic yard (including forms)	$112.58
0.95 cubic yard concrete, around tie rods and in cylinder filling at $14	13.30
54 lineal feet timber piles (untreated) at 28 cents	15.12
10 lineal feet fender piles at 30 cents	3.00
66 board measure feet timber at $36 per thousand	2.38
112 pounds steel tie rods, washers, etc., at 7 cents	7.84
Approximate contingencies, royalty, and engineering at 20 per cent	30.84
Cost per foot run of wall	$185.06

Note: Filling not included.

Comparison of Costs of Wharf Walls Shown in Fig. 38

(The following estimated costs per lineal foot of wharf wall are based upon Pacific coast prices of labor and material during 1920)

Type	Cost per lineal foot
No. 1	$340
No. 2	410
No. 3	740
No. 4	420
No. 5	148
No. 6	170

River and canal revetments to retain fill and prevent erosion are shown for Hamburg, under conditions of fresh water and fixed water levels (Figs. 39 and 40).

Precast Concrete Caisson Bulkhead.—Another type of bulkhead or sea wall is the precast concrete caisson. A recent example of this type is found in the construction of the China Basin Terminal at San Francisco. The terminal building is 812 feet long and six stories high, supported on a pile foundation protected by a row of three-compartment caissons, 29 feet by 7 feet 6 inches in cross-section, which extend to a depth of 57 feet below the deck of the wharf. Forty of these caissons were precast on shore and allowed to season 28 days. They were launched and towed to the job and sunk into holes excavated to depths of 6 to 18 feet in the hardpan. These excavations were made by blasting and removing the spoil with orange-peel bucket on a floating derrick. When set in final position, the fourty caissons were 14 feet 6 inches apart, with the 20-foot sides at right angles to the wall. The spaces between the caissons and the sides of the holes in which they were set, were filled with crushed rock, tamped

into place by a tamping bar and floating derrick. The bottoms of the caissons were then broken out and fifteen piles driven through the bottom to a penetration of 12 to 20 feet. The caissons were sealed by depositing

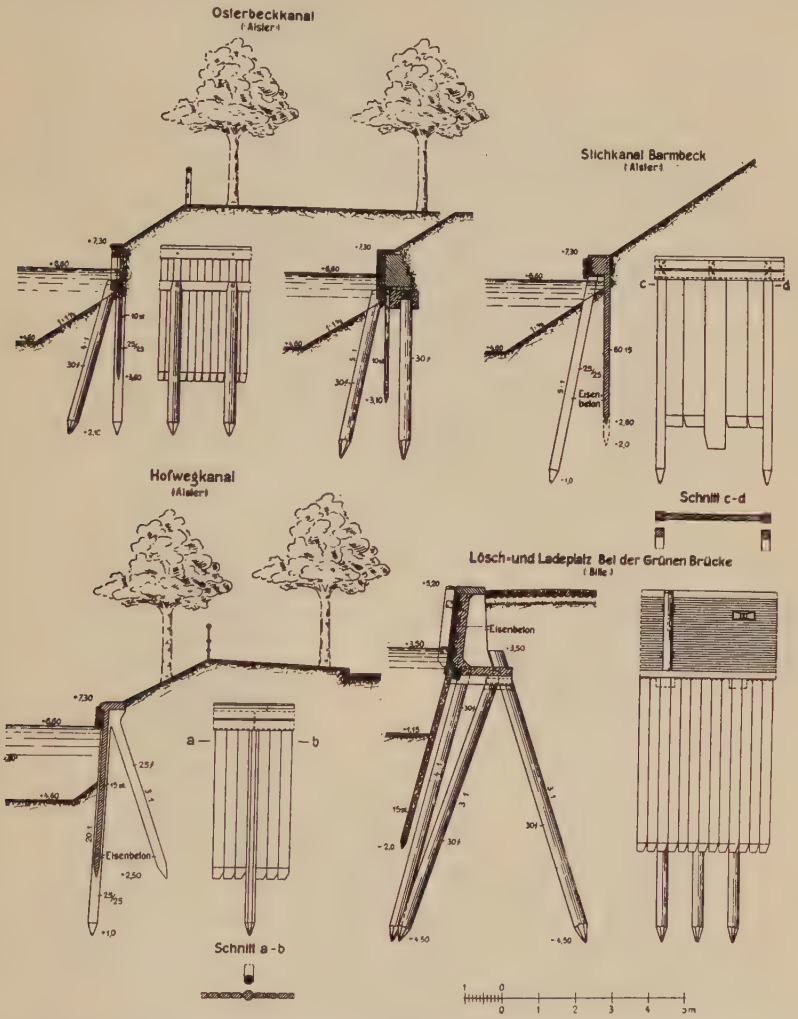


FIG. 39.—Types of canal bulkheads and revetments at Hamburg. Fresh water and fixed water levels. The little stream, the Alster, is dammed, forming a large central lake of about the size and location of Central Park, N. Y., with several connecting canals.

10 feet of concrete around and over the heads of the piles which had not been cut off, but left projecting.

The reinforced-concrete curtain walls closing the space between the caissons at the inshore ends are arches 1 foot in thickness; each curve is a quadrant of a circle. The sections were cast with tongue and groove

horizontal joints. The fill is then placed behind the wall and the face of the wall protected by fender piles. The caissons serve as anchor piles, and, with the quadrants, form a tight sea wall or bulkhead, the caissons themselves supporting the wharf apron that, in ordinary construction, is carried on piles. This seems to be an exceptionally substantial wall

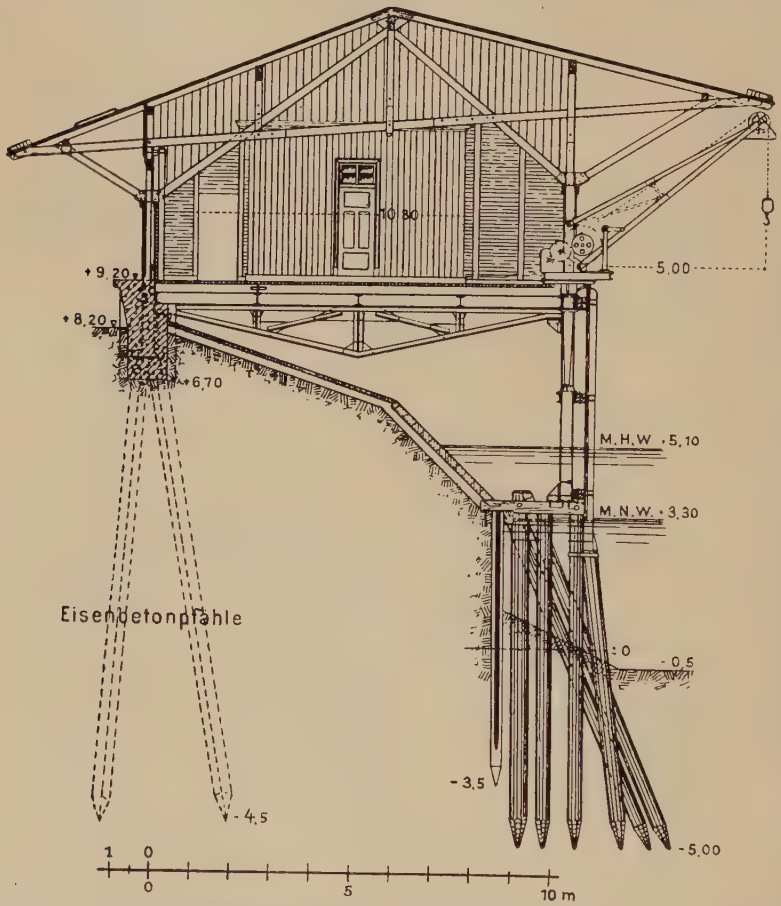


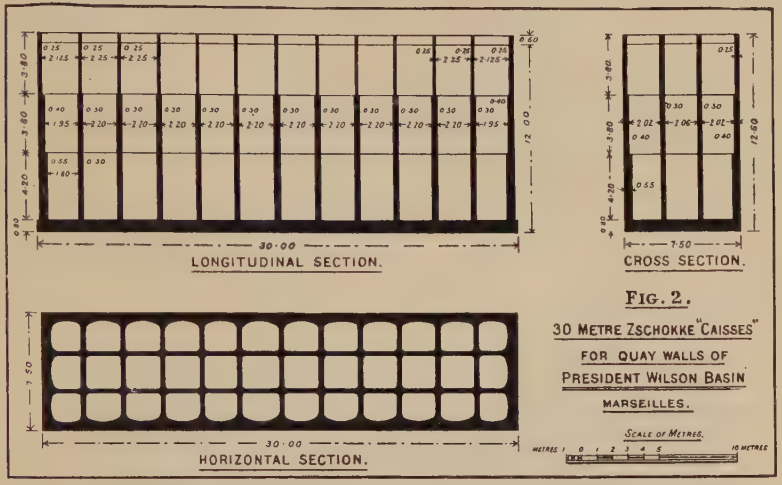
FIG. 40.—Customs inspector's house on the Customs Canal (Zollkanal) boundary of the free port, Hamburg; showing unusual foundation piling and bridge floor over a stone-faced revetment to low water and sheet piling bulkhead or retaining wall.

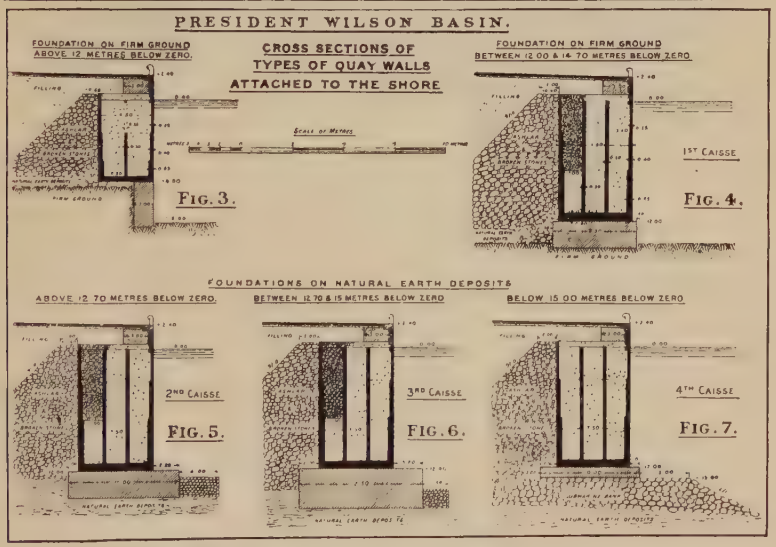
for an inshore that is to carry a heavy fill, such as, in this case, a six-story warehouse. The life of this structure will be followed with much interest.[1]

A similar precast caisson type of construction is nearing completion at the President Wilson Basin, Marseilles (Fig. 41).

[1] WHITE, FRANK G., Chief Engineer, California Board of State Harbor Commissioners, "Concrete Caissons Sunk in Place for Wharf and Seawall," (Seawall for China Basin Terminal on San Francisco Bay consists of caissons 57 feet deep connected by concrete arches placed in precast sections), *Eng. News-Record*, Vol. 91, No. 7.

Precast Cellular Caissons.[1]—The new President Wilson Basin at the Port of Marseilles, France, has been constructed by sinking large precast cellular caissons on a prepared bed. The system was developed by the





(*Dock and Harbour Authority, October*, 1924.)

FIG. 41.—President Wilson Basin, Marseilles. Precast concrete cellular caisson construction.

successful bidding contractor, M. C. Zschokke. The depth of the basin is −12 meters under datum plane, about 40 feet. The bottom is prepared by going to hardpan and laying a concrete slab up to −12 meters level by

[1] Data from SAINFLOU, GEORGES, Ingenieur Ordinaire des Ponts et Chaussees, Marseilles. "Quay Construction at the Port of Marseilles," *in The Dock and Harbour Authority*, London, October, 1924.

means of movable high air pressure caissons. The concrete cells 30 meters long by 12 meters high by 7.50 meters wide are divided by two longitudinal and eleven transverse partitions. The "beehive" is cast in dry dock using moving metal forms similar to grain silo construction. The mixture is 350 kilograms cement, 400 liters sea sand, and 800 liters gravel. After aging for 30 days the cells are ballasted and towed to position. The valves are opened and the section sunk onto the prepared bed that varies according to bottom conditions as shown in cuts, 3 to 7, on Fig. 41. The water is then pumped out of the cells and these are filled with a two-mortar and three-stone mixture.

The inshore row of cells above the −7-meter level are filled with riprap. The quay wall, fill, and deck above the water line are built up above the cellular *caisses* foundation. The quay wall face to +2.40 meters above datum is granite masonry. It may be added that the space between *caisses* when sunk averages about 60 centimeters (2½ feet). Divers splice in a cofferdam, a small curtain wall, and the space behind is filled as the other cells. The result is a solid concrete quay wall the length of the quay, to 12 or more meters below water and 7½ meters wide. Such a structure should be immune from decay, deterioration, or subsidence, and therefore, for generations, require no maintenance, except fender piles, rails, and paving surface.

Modifications of this system would be possible in limnoria infested waters where hardpan is quite deep, by driving piling well below the mud level, and capping with a concrete slab to receive the "beehive."

4. FIRE PREVENTION

Fire Protection and Prevention.

New Orleans, Nov. 21, 1922. (*News Item.*) Sparks from a switch engine started a fire on the levee here, which destroyed 2,000 feet of wharfage and did property damage estimated at from $2,500,000 to $4,000,000. A new banana wharf, eight box cars filled with government material, and two government derricks were destroyed. The steamship *Poncelat* was damaged, together with a mass of export goods on the wharf. The Mexican gunboat *Saragoza*, the steamer *Truxillo*, and a government barge were towed into the stream and saved (Fig. 42).

This news item is characteristic of many, throughout the year, announcing disastrous waterfront fires which annually destroy many millions of dollars worth of structures, merchandise, and ships.

A description of the rapidity with which fires spread is given by Charles H. Fisher, Chairman of the Committee on Docks, Piers, and Wharves of the National Fire Protection Association.[1]

The fire at the Weehawken Terminal of the Erie Railroad in 1921 resulted in a loss of practically $2,500,000. This property consisted of three two-story and one one-story ordinary wooden piers, with a four-story brick and a one-

[1] Before the Society of Terminal Engineers, Mar. 13, 1923.

story iron warehouse on shore. The ordinary fire protection included outside hydrants along the bulkhead, inside stand-pipe system, water casks and pails, fire extinguishers, alarm system, fire brigade, watch service, and the public fire departments of surrounding municipalities, the powerful fire tugs of the New York Fire Department and thirty-seven railroad tugs of different systems, equipped with fire pumps. The progress of the fire in the face of all this fire fighting equipment was as follows: 11:40 p.m. started on pier D; 11:58 p.m. both floors ablaze, flames bursting from side walls, low wind velocity; 12:09 a.m. twenty-two barges in the slip to the North ablaze and south side of pier C burning briskly; barge hawsers burned through, and burning barges floating against pier C; 12:35 a.m. pier C fully ablaze, brick warehouse afire; 12:50 a.m. pier B burning; 1:18 a.m. pier B completely ablaze; 1:45 a.m. pier A burning; 2:00 a.m. pier A burning fircely.

(*Photograph by the author.*)

FIG. 42.—Wharf of the New Orleans Army Supply Base destroyed by fire in the exposed wooden piling. This caused failure of steel and concrete superstructure.

Fighting this fire were engine companies from Weehawken, Union Hall, Hoboken, Jersey City, and of the Erie Railroad. Operation of land force extended only about 75 feet from the shore, the piers being inaccessible. In the marine fire force were three New York fire tugs and thirty-seven railroad tugs. Because of the intense heat in the narrow slips the marine operations were confined to the ends of the piers, therefore the large middle portion of the piers were inaccessible to fire fighters from both the water and shore ends. The only reason the fire was not larger is because there were no more piers to burn.

The possibility of the loss of life in such a fire is illustrated by the great Hoboken fire of 20 years ago, in which 150 lives were lost, including members of crews and passengers on the passenger ships of the North German Lloyd, which were ready to sail the following morning.

The loss of the wharf at the Army Supply Base at New Orleans illustrates the difficulty of fighting a fire in the wooden pile substructure of a pier:

All experience in the past has proved that when a fire involves the lower side of a combustible substructure it is next to impossible to extinguish it. This wharf was about 170 feet wide and 2,000 feet long. The deck and floors were of ordinary wood construction. Fire walls were placed at 200-foot intervals; these

were provided with 15-foot "T" or wing walls at each end. The platforms on each side of the wharf at each fire wall had a 15-foot concrete section, all intended to check the spread of fire from one side of the wall to the other. Unfortunately, when this wharf was built the stage of the river was very high. Therefore, the concrete footings for the walls, which were carried on independent wood piling, were placed about 7 feet below the pier deck which was about the stage of the river at the time. At the time of the fire, the stage of the river was about 15½ feet below the footings of the fire walls, with the result that the fire swept from one section, under the fire wall, to the next section, and so on until the whole wharf was destroyed.[1]

The fire of the North German Lloyd just mentioned was caused by throwing a bale of burning cotton into the slip. The tide carried it under the pier, resulting in the loss of 150 lives and five million dollars' worth of property.

The Fire Record.—Probably the best way to direct attention to the necessity for regulations is to refer to the fire record (The United States and Canada).[2]

This record is obtained through the cooperation of twenty-one insurance inspection bureaus, and all the railroads having marine terminals. Up to Jan. 1, 1923, the record included 149 fires, extending over a period of 33 years, with a total loss of $36,247,425, or an average of $243,271 per fire. While it is admitted that the loss record is not complete and, therefore, is not a true index, still it must be recognized that it is the best and most complete record for this class of property. The average loss of $243,271 per fire is indeed the record for all classes of property.

In considering the average loss per fire in all classes of property, it is generally recognized that average losses below $900 per fire are low, and when they exceed $1,500 per fire the average is very high. In manufacturing properties the average loss per fire approximates $6,000. A comparison of these average losses of $1,500 or $6,000 with those obtaining on piers and wharves of $243,271 per fire emphasizes the great need for improvements. This fire record most emphatically confirms the feeling of fire department authorities and fire protection engineers that fires originating in piers and wharves, as ordinarily built, unless extinguished in the very early stages, develop into very serious losses. The reason may be found in the prevailing class of construction (light constructed sheds of unprotected steel and corrugated iron or wood on open wood piling), tremendous unbroken areas, inadequate fire protection, concentration of enormous values, a multiplicity of hazards and, frequently, indifference by the wharfinger.

Where steel columns and girders are used, they should be protected against attack by fire, as any considerable amount of heat developed will cause twisting, distortion, and failure of the structure. Many incombustible land and marine structures have failed because of the lack of protection on the steel members.

[1] Fisher, Charles H.

[2] Studies of the Committee on Docks, Piers and Wharves of the National Fire Protection Association.

Therefore, wharves are great fire hazards, because of the construction, of contents, and of exposure to other fires. As to construction, Chief Kenlon, in his book "Fires and Fire Fighters" describes piers as:

> . . . comparable to nothing but horizontal flues, through which flames rush with a lightning-like rapidity, rendering abortive any efforts on the part of the fire department, unless the greatest promptitude is shown by all concerned.

Causes of Fires.—*Certain cargo* are themselves fire hazards by spontaneous combustion, such as cotton and oils, not to mention explosives, which should always be handled separately from other cargo along with petroleum products.

Broken packing and other refuse on the pier is a constant fire risk. Usually there is a great deal of litter and every effort must be made to keep the wharves, sheds, and warehouses free from all litter.

Carelessness on the part of employees and other persons on the wharves, particularly with regard to smoking, is another cause. Great vigilance must be exercised at all times to enforce the "No Smoking" rule.

Fire fighting is delayed because hydrants and passages are not kept clear, and or because the fire is not detected in time.

Exposure fires, i.e., fire spreading from some other ship or wharf, or burning oil on the water, floating bales of burning cotton, or sparks from a locomotive, etc., are more prevalent in waterfront fires than inland. This is due to the greater number of, and intrinsically greater, fire hazards, and the usually higher winds which carry brands or sparks.

Fire Prevention. *Fire Patrols.*—On old wharves the greatest precautions must be exercised. There should be a rigid fire patrol with a drilled fire brigade of the employees; there must be watchmen clock boxes to insure regular rounds, and fire alarm boxes at frequent intervals, both accessible and well marked. There must be accessible and conspicuous fire buckets and chemical extinguishers, and these should be frequently inspected. In severe weather they freeze and become useless. The personnel should be trained to turn in an alarm first and then give first aid fire service until the fire department arrives. Above all, *the wharves must be kept clear of rubbish.*

Sprinkler Systems.—Even old piers may be fitted with sprinkler systems. In climates with freezing weather, the dry-pipe system is necessary. By this method, the sprinkler pipes are filled with compressed air back to a valve at a point where the water is protected from freezing. When the heat of a fire reaches a sprinkler head on the wharf, it causes the air to escape from the pipe. This reduction of the air pressure to one-sixth of the water pressure will open the water valve, and the flooding of the fire will begin.

Drop Partitions.—In old or new piers, there may be difficulty in catching sufficient heat in the high and draughty sheds to open the valves.

The prompt opening of heads will be assured, and also the spread of the fire through the pier will be retarded by means of longitudinal and horizontal drop partitions from the roof to the level of the lower roof trusses. The sprinkler heads located in the corners of these partitions will catch the heat much more readily.

Larger mains and heavier water pressure are required on wharves in excess of the usual sprinkler practice because of the great areas to be covered and the large number of sprinkler heads that may be opened at the same time.

Because of the danger of exposure fires, there may well be installed outside sprinklers for the roof and sides of the wharf structure.

In connection with the automatic sprinkler heads, there should be a system of automatic fire alarms that will send in an alarm to the fire department as soon as a sprinkler head opens.

Fire Prevention in New Construction.—All wharf structures should be of concrete, steel, stone, or other fire resistant material above the water line. In wharf layouts of the quay type, it is usual to separate the sheds by fire breaks. At least fire walls are installed at frequent intervals, usually of 500 feet. This is difficult in long piers, as these walls interfere to a great extent in the movement from the outer end of the pier to the shore. At least draught partitions in the form of roof drops, mentioned above, should be frequent.

As to the superstructure, the shed frame work, the latest efforts have developed a system of concrete-coated steel construction. The structural steel collapses in 15 minutes in the case of a full-fledged fire. To give greater resistance the usual structural steel frames are covered with wire lath and trowel-coated with concrete. The result is a light, fire-resisting frame. Wire glass and also fire doors should always be used for partitions in spite of the protests made by most pier superintendents. The best fire-resisting roofing is tar and gravel on an asbestos base of some sort.

The committee[1] summarizes fire preventive measures:

> All stairs, elevators, escalators, and chutes, and all offices, rest, auction, rigging, boiler, and other rooms with hazardous occupancy should have fire resistive enclosures. There can be little question about the importance and value of such enclosures as statistics show very plainly that unprotected vertical openings facilitate the rapid spread of fire from floor to floor. The hazards incident to the various room occupancies should be cut off so as not to endanger the cargo.
>
> On each side of each fire wall, and at 100-foot intervals, fire hatchways in the center drive of the pier deck are provided for. Suspended under each hatchway there is a platform from which the fire fighters may operate against any fire under the deck. Additional means for attacking a fire under the deck are provided for by arranging small openings in the deck, at 20-foot intervals longi-

[1] Committee on Wharves, Docks and Piers of the National Fire Protection Association.

tudinally and transversely, each opening to have a substantial cast-iron cover. It is impossible to overestimate the importance of previously arranged means for attacking fire under the decks of wooden construction. Chopping holes through thick decks generally proves too slow for the fire and placing nozzles and hose lines at the side of the pier below the deck is almost impossible in time for efficient service.

The recommendations include a fire bulkhead; light protection for the structural iron and steel; three light forms of fire wall; fire hatchways; openings for revolving nozzles and cellar pipes; fire resistive enclosures for stairs, elevators, escalators, chutes, offices; rest, auction and other rooms with hazardous occupancy; all of which have been referred to previously.

Miscellaneous.—In this section it is recommended that slips and wharves be of sufficientwidth to permit of the free movement of vessels and auxiliary craft on each side of the slip, with enough space between to enable fire boats to maneuver. They should be not less than 250 feet wide. The fire at the Erie Terminal demonstrates the danger of narrow slips. These were 125, 142, and 196 feet wide.[1]

Oil Pollution of Harbor Waters.—The oil pollution of harbor waters has come to be a serious fire hazard. Segregation of all oil handling and operations in a petroleum harbor, as is the practice in European ports, is a protection against the spread of large quantities of cargo oil. This does not, however, prevent the pollution of harbor waters with sludges from bunker tanks of oil-burning vessels. The oil, in the form of a viscous, tarry mass, spreads over the surface, and is carried by the action or tide and wind and deposited upon beaches and harbor structures, where it forms a coating, extending from low water to high water. This has led to much remedial investigation and legislation. The opening paragraph of a suggested ordinance reads as follows:[2]

Be it ordained by the City of ..... as follows:

1. That it shall not be lawful to throw, discharge, or deposit, or cause, suffer, or procure to be thrown, discharged, or deposited, either from or out of any ship, barge, or other floating craft of any kind, or from the shore, wharf, manufacturing establishment, or mill of any kind, any oil, fuel oil, oil sludge, material containing oil, or any other oil refuse, or refuse matter of any kind or description whatever, into the waters forming the harbor of ..... or into any other streams or waters within the corporate limits of the city of ..... but this shall not be construed to prohibit the discharge or deposit of refuse matter, except oil, fuel oil, oil sludge, or other oil refuse, into the streets or sewers and passing therefrom in a liquid state into such waters.

Efficient remedies have been devised for removing oil from water before discharging overboard. Oil-burning ships carry their fuel in double bottoms, as well as in side bunker and athwart ship bunker tanks. When the oil has been consumed, the tanks are pumped full of salt

[1] *Ibid.*

[2] See also "British Law" in Appendix I.

water to maintain trim. Before fuel oil can again be taken, this salt water, mixed with sludge, is dumped overboard. A system has been devised for separating the oil from the water before the contents of the tanks goes overboard. Another device is an oil skimmer, which is said to skim the oil from the surface of harbor waters. Skeptical mental reservations are to be held.

All of these devices to lessen the fire hazard of water terminal property and ships must undoubtedly continue to receive much study and careful consideration.

MAINTENANCE

Maintenance Considerations in Port Terminal Planning Fully as Important as Depreciation or Obsolescence.—Heavy maintenance costs will ruin any port operation. Therefore, along with the consideration of the probable useful life of a port terminal, from the standpoint of obsolescence and construction materials chosen according to such an estimate, there must be considered the cost each year of keeping the plant in a serviceable condition. First costs are capital investments and come from the bond issues, but maintenance costs are part of operating costs and come out of income. It is far better to issue a few more millions of bonds and build the terminals substantially in the beginning than to have maintenance costs so very high that the income is swallowed up and the yearly balance sheets of the enterprise never show black figures to the hypercritical voters and taxpayers. It is easier to put over a little more capital investment in the enthusiasm of the original campaign than to ask for taxes to meet a port operating deficit. The shoddy, or badly constructed port can easily require more maintenance than the interest on several millions. Also extensive repairs interrupt operation with resulting loss of revenue.

Causes of Deterioration.—Some of the causes of deterioration to wharf structures may be enumerated:

1. To foundations under water by marine borers.
2. Subsidence or settling of foundations.
3. Injury to wharf face by contact of vessels.
4. Decay of timber parts because of heat and damp is greater in waterside structures than inland buildings.
5. Rust of rails, structural steel, and sheet metal, for same reasons.
6. Injury to sheds and decks by swinging loads or moving trucks.
7. Wear of decks by traffic.
8. Erosion from locomotive gases or from various types of cargo.
9. Clogging or rusting out of drains.
10. Leaky water mains and pipes (or burned out electric cables) often due to settlement of foundation.
11. Fire and/or wind storms.

12. Dredging of slips in estuary ports with heavy silt deposits. Marginal wharves may be far more economical with regard to annual dredging because the current conditions may cause a natural scour. For instance, in the Cooper River at Charleston the marginal wharves at the Army Base and at Columbus Street require almost no dredging. The Union Pier slips silt 1 foot a month and dredging costs $36,000 annually for the two slips.

Sheds.—The most economical sheds for maintenance are reinforced concrete or reinforced concrete columns and brick (fire brick) paneling. Cast iron columns require less frequent painting, but interior columns do not require frequent painting anyway. Cargo masts and other outside structural steel require painting every 5 years at the extreme limit. All structural steel work and roof trusses should be of as simple design as possible to facilitate painting.

Corrugated steel (18-gage minimum) is much used as transit shed material, but, with low first cost, it is the most expensive in the long run. It is easily damaged by blows and the vast areas require frequent painting to preserve the material and also to preserve a shipshape appearance. Major Du-Plat-Taylor[1] puts the limit of life of galvanized corrugated steel sheeting at 15 years. He suggests timbers around doorways and along cornices to protect the structure from damage from rolling or swinging loads.

Corrugated steel sheeting for temporary structures is unexcelled because of economy of transportation, many sheets occupying a very small cubic, and speed and economy in erection. This characteristic of metal sheeting made possible the fabulous speed attained by the Service of Supplies American Expeditionary Forces, under General Jadwin in France, in erecting the great depots. But for a structure that is intended to serve for several decades, the initial advantages will be outweighed by eventual high maintenance costs.

Gutters and drains should not be an object of undue economy as flimsy and undersized gutters will sag, clog, overflow, and cause excessive damage to cargo as well as structures. Extreme cases of excessive rainfall should be taken as the basis. Penny wise is pound foolish in undue economy of drains and gutters. Also they should be easily accessible to make unnecessary tearing up of floors and decks for repairs.

Shed Roofs.—Corrugated steel sheeting for roofing has the same advantages and disadvantages as for walls. Leaky spots are difficult to repair.

Slate roofs on substantial sheds are desirable because laid in small units they are easily repaired by replacing. Copper, not steel, nails should

[1] Du-Plat-Taylor, Major M., M. Inst. C. E., M. I. Mech. E., "The Upkeep of Dock and Harbour Premises," in *The Dock and Harbour Authority*, October, November, December, 1924.

be used. Slate roofs permit of a very economical method of top lighting recommended by Major Du-Plat-Taylor and in general use in England, by substituting glass tiles for the slate at frequent intervals. The economy of both construction and maintenance is obvious and the efficient lighting obtainable is very helpful in operating sheds economically.

The various forms of bituminous roofing are justly popular in American practice. They are economical, quickly constructed, easily patched, and, if properly maintained, will last for a long time.

Floors.—Wooden flooring is most uneconomical because of excessive wear and rot. It soon becomes rough, slowing down the speed of trucking as well as the size of loads and wear on rolling equipment. Also wooden flooring must be made double to prevent leakage of loose cargo from broken bagging. Furthermore, it absorbs many kinds of cargo handled over it and the wharf thereby becomes unsuited for other kinds of cargo that afterwards cannot use the wharf.

An example may be cited without derogatory criticism of any engineer because the effects are the result of war conditions, not free volition. The great Army Supply Base at Charleston (called Port Terminals) has not been maintained between 1919 and 1925, nearly 6 years. When the United States Shipping Board and the Charleston Port Utilities Commission began reconditioning, the degree of deterioration of various materials in a semitropical climate could be observed. It made a splendid laboratory.

Creosoted wharf apron piling, except fender piles damaged by vessels, were found in perfect condition. Concrete, inverted, U-shaped, fire breaks were the same.

Fire-brick walls of transit sheds and warehouses were also in perfect condition. Iron work, turnover doors, and cargo masts needed painting but otherwise they were in good condition.

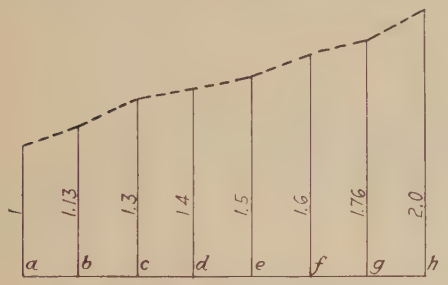
Interior wood structural members, columns and roof trusses, were in good condition, but during the period of inactivity of the Base for 2 years, 1921–1922, these members narrowly escaped destruction because the sheds and warehouses were closed and dry rot almost got a start. Discovered in time the sheds and warehouses were kept open and ample ventilation prevented further deterioration.

Sprinkler system heads, valves, and pipes were found in perfect condition.

But all untreated wooden flooring inside and out had gone to pieces as had also wooden marquise awnings. This flooring had been laid, in wartime haste, of untreated timber. The plans called for sand fill to deck level, but, time being pressing, the fill was not carried above ground, or street, level leaving unventilated air chambers between fill and floor, with ensuing rapid decay. Even the deck of the wharf apron, although open to ventilation from the river side, went to pieces as rapidly as unventilated

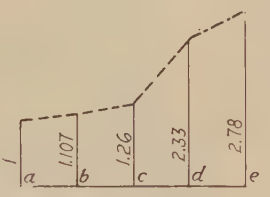
sections, both inside and out. The creosoted piling was solid, but the untreated heavy timber beams or sleepers laid across the piles and the deck planks on the beams became entirely decomposed within 6 years. Those portions of the wharf that were used the least were in worse shape than the berths that have been in frequent use, illustrating the old adage that you rust out faster than you wear out. Moral: Treated timber, ventilation, use!

Concrete Floors.—The usual practice in solid fill structures is a 6-inch layer of 6:1 bottom concrete with a $2\frac{1}{2}$-inch granolithic concrete surface. This is a mixture of concrete with granite chippings, care being taken to screen out granite dust. This gives a hard wearing surface having less abrasion from truck wheels than ordinary concrete. Such floors, however,



(From Major DuPlat-Taylor in Dock and Harbour Authority.)

FIG. 43.—Comparative cost of maintenance, floors.



(From Major DuPlat-Taylor in Dock and Harbour Authority.)

FIG. 44.—Comparative cost of maintenance, sheds.

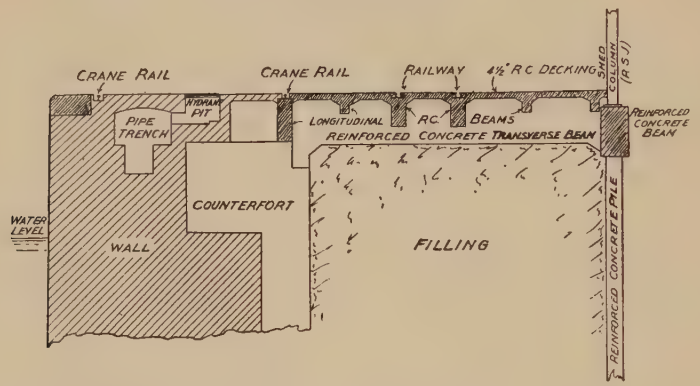
cannot be readily broken up to get at broken drains, etc. Therefore, all drain-pipe channels or tunnels should be provided with separate slabs of convenient length and fitted with a plate or socket that may permit their being lifted out when necessary to reach the tunnel, thus avoiding one of the most costly and annoying of maintenance operations, the tearing up of floors.

Granite cubes for flooring are much preferred in European ports and cities. In Berlin the sidewalks are of 10-centimeter cubes of stone laid over a tamped-down sand bed and washed over with sand and water instead of grouting. The walking surface is not quite so smooth as cement but when a drain or water pipe must come up the little blocks are quickly taken up and after the trench is filled, they are as quickly relaid. Such operations with small cube pavements require little labor and no loss of material. They wear for years. In Havre and other French and Belgian ports, 6-inch granite cubes are laid over a tamped-down sand base and washed in with sand and water. Major Du-Plat-Taylor strongly recommends granite blocks for quay side, transit shed floor, and runway paving. The English practice is to lay the 4-inch granite cubes on a 1-inch mortar

surface of the 6 inch 6:1 concrete base and grout with pitch. When worn the cubes are taken up, reversed, and relaid.

According to English practice the varying maintenance costs with different types of sheds and flooring are given by Major Du-Plat-Taylor in these diagrams (Figs. 43 and 44).

Subsidence.—There is always a tendency for the shed floors to settle or subside, with the consolidation of the fill. The same thing occurs occasionally in open-pile wharves. The tendency of the wharf apron and the shed or quay floors behind the bulkhead-sheet piling wall to part company is observed in most waterfront structures. Either a separation or only a settling of an inch or two will destroy the grade necessary for drainage and for washing down the decks. Major Du-Plat-Taylor has an obvious solution to prevent settling of tracks and crane rails on the



(*DuPlat-Taylor.*)

FIG. 45.—Shows a quay supported by reinforced concrete beams, as suggested.

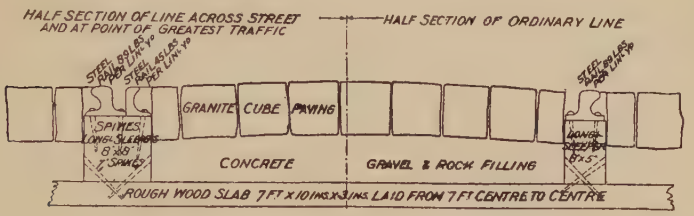
wharf and the subsidence of the shed floor, by supporting the paving on reinforced concrete beams uniting the foundation blocks under the front of the shed with rail beams and wall. It is best practice to unite all the piles under the walls of sheds by continuous beams, and these will also form supports for intermediate cross-beams under the quay and shed floor (Fig. 45).

A case is mentioned where the fill settlement was such that it was necessary to rip up the entire quay, rails and all, fill in with hard fill to level, and relay the entire quay, an enormous expense saddled upon maintenance.

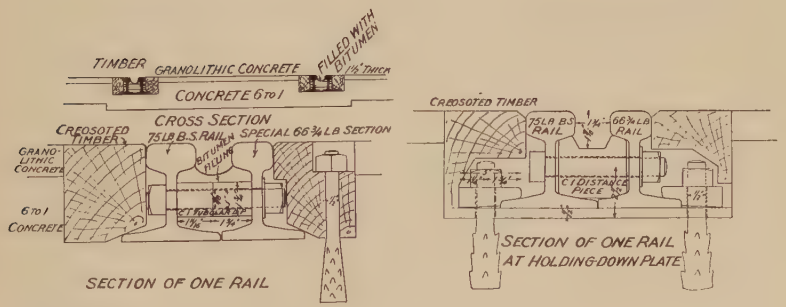
Replacing Rails.—Crane and railroad rails must be relaid from time to time. If provision can be made in the original construction with this in view, future maintenance costs can be materially reduced. In Liverpool it is necessary only to take up two rows of cube paving blocks to remove the rail. At London with a concrete wharf removable, creosoted (at

least in America they would be) timbers parallel the rails, as clearly shown in Fig. 46.

Pitch of Floors and Subsidence.—Attention must be given to the pitch of the floor to insure easy drainage. A mistake in this direction was made in the Army Base at Philadelphia. In this otherwise well-constructed work the concrete deck slab or floor is perfectly flat. In settling, depressions formed of 1 to 2 inches below designed floor plane. When a driving rain sets in across the river the water is forced into the shed-warehouse under the doors and floods the floor, collecting in the depressions. This causes much labor and expense, as large amounts of


HALF SECTION OF LINE ACROSS STREET AND AT POINT OF GREATEST TRAFFIC
HALF SECTION OF ORDINARY LINE
GRANITE CUBE PAVING
CONCRETE
GRAVEL & ROCK FILLING
ROUGH WOOD SLAB 7 FT X 10 INS. X 3 INS. LAID FROM 7 FT CENTRE TO CENTRE

a



(*DuPlat-Taylor.*) *b*

FIG. 46.—Where railway lines are laid on quays it is necessary that they should be choked for the full length. It is also desirable to make provision for lifting, packing up, or relaying the rails without breaking up the quay surface. One or two forms of track are shown: (*a*) can be done by taking up one or two rows of granite cubes in this instance; (*b*) is a type adopted in the Port of London, in concrete quays. The rails can be attended to by taking up the longitudinal timbers.

dunnage are required and a force of men is necessary to batten the doors in a driving rain to keep out the water. The transit shed floors and pier decks should have a sharp pitch from the center of the pier to insure easy drainage and flushing of the floors with a fire hose when cleaning is necessary.

F. G. White at San Francisco has developed a door with a small "T"-iron shape across the bottom. The tongue of this shape fits into a groove

in the threshold, making a tight joint or weather strip that will keep out a driving rain.

These few illustrations are only examples calling attention to the principle that: *the first cost of port terminal structure within wide limits is less important than future costs of operation and maintenance; and, a higher first cost that will reduce and facilitate future repairs to the property is essential to success in port terminal operation.*

PART II
GENERAL CARGO WHARF EQUIPMENT

CHAPTER V

GENERAL CARGO TRANSFER—WINCHES, DERRICKS, CRANES, CONVEYORS[1]

In handling the cargo of a ship two things are to be desired, speed and economy. Speed is economy because a ship in port is a liability and is only an asset when at sea. Sometimes the cost of handling the cargo is offset by the increase in the speed. Sometimes reductions in the cost of handling are only illusory because the reduction of handling expenses is accomplished with a lengthening of the time of the ship in port. Usually it is possible to reduce handling expenses and speed up the turning around of the ship by the same methods. In the study of the situation, however, the time element as well as economy of operation must be kept in the foreground.

There are two distinct movements involved, "transference" of cargo from ship to wharf, and "handling" of the cargo on the wharf. Transference is of two kinds, from side ports as is the case in all lake and coastwise or river boats, and from the hatch in the case of ocean vessels. The first is a lateral movement and the second a vertical movement, or the first is a low trajectory and the second a high trajectory. Handling the merchandise on the wharf consists of three general operations,—sorting, tiering, and delivery to various land and inland water carriers.

Side Port Discharge.—This movement is generally accomplished by longshoremen with hand trucks passing back and forth between the vessel and shore along a gangplank.

Side Ports and Water Level.—The variation in the water level due to tides or river conditions will greatly affect the grade of the gangplank and the efforts demanded of the men to move the goods up the incline. At Boston and elsewhere the tide variations have been hard to meet. To accommodate the coastwise trade with side ports, the wharves have been built with adjustable ramps, and mechanical aids to the longshoremen have been installed. The best known is the Reno Conveyor of the Otis Elevator Company. These are quite generally used in the ramps of all coastwise steamer wharves such as the wharves of the Clyde Line, Merchants and Miners, Old Dominion, Ocean Transportation Company, etc.

We have interviewed C. H. Maynard, General Agent of the Merchants and Miners Transportation Company, Pier No. 2, Northern Avenue,

[1] See also Cunningham, Brysson—"Cargo Handling at Ports," London 1924.

Charlestown, Massachusetts, and found him very enthusiastic about his inclined elevators (1923).

He states that their use increases the efficiency of their freight handling in and out of the boats fully 40 per cent—that during the past year he has handled 334,000 tons of material of all kinds and descriptions on these hoists. Before the hoists were installed it was impossible to unload the freight cars from the car-floats when the tide was low, and this meant a delay of 3 to 4 hours waiting for the tide to reach a point about half-way to high. Even then it was hard work to unload until almost high tide. With the hoists it is possible to unload at all times regardless of tide. The work is made much easier for the men and it requires a great many less men to do the same amount of work. In fact, Mr. Maynard stated, at times when the conveyors had been out of commission temporarily and the tide was half-way between low and high it required about four times as many men to unload the cars as when the conveyors were running.

The average cost of an incline dock elevator is about $5,000. This, however, does not include the cost of a ramp and the wharf drop used in connection with this equipment. It is customary for the purchaser to furnish these items.

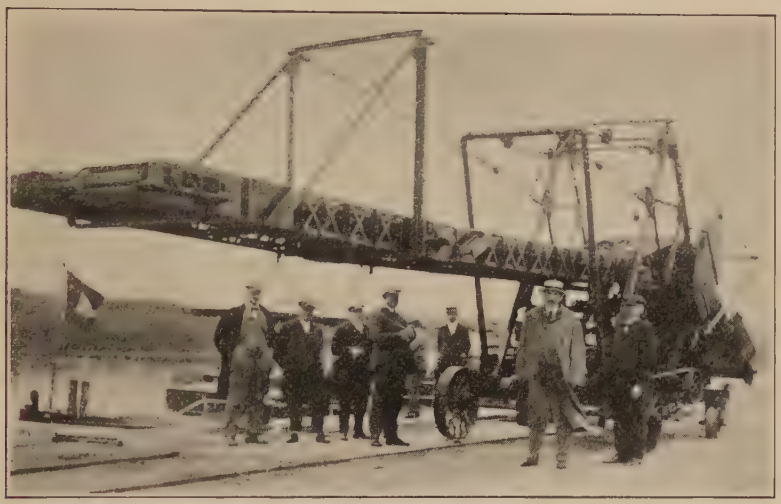
Portable Conveyors.—Another machine which has been put on the market and is gaining in popularity for side-port transfer of cargo is the portable conveyor. A section operated by its own electric motor driven by a plug and cable connection with the main power line is pushed from the wharf into the vessel. The conveyor is simply a moving gangplank. It has the advantage over the Reno type that the longshoremen do not need to pass to and fro between ship and wharf, but may work at each end of the animated gangplank. On the other hand, the machine is more expensive. The municipal wharves of New Orleans are equipped with several of these conveyors.

In all types of machinery the use depends upon the relationship between the time and labor required to adjust the equipment and the amount of cargo to be transferred, taken together with the price of labor.

The use of movable, portable conveyors is increasing. The example shown in Fig. 47 is one at the New York State Barge Canal wharf of the General Electric Company in Schenectady. Many of the Army Supply Bases were equipped with these portable electric belt conveyors of different makes.

Gravity Roller Conveyors.—At the port of Charleston, the Army Supply Base has a large number of gravity roller conveyors and electric-driven belts in the usual 30-foot lengths and longer. In discharging Pacific coast canned goods and shingles these are used together from ship side across the transit shed to cars 280 feet distant. In the loading and discharging of seaboard vessels and barges, as well as box cars,

frequent use is made of the gravity roller conveyors. These in short lengths are also used in the hold of the ship to distribute to the wings (Fig. 48).



(Photograph by the author.)

FIG. 47.—Portable conveyor "in marching order" ready to move to the point of action at the New York State Barge Canal Terminal, Schenectady, at the plant of the General Electric Company.

(Photograph by the author.)

FIG. 48.—Gravity roller conveyor in use at the Barge Canal Terminal of the General Electric Company at Schenectady, New York, between box car and canal boat.

Conveyors and Elevators Defined and Classified.—In a paper read before the Armstrong College Naval Architects' Society, Gardiner Mitchell of Aberdeen defined *a conveyor as a machine carrying material con-*

tinuously in a constant stream from its receiving end to the delivery point or points. Conveying machinery might be divided into approximately nine distinct classes, namely, spiral, screw, paddle, belt, gravity bucket, tray, slat, push-plate or scraper, and drag-link, each type being specially suitable for dealing with certain kinds of material.

Paddle conveyors were similar in construction to the spiral, except that on the shaft were fitted fan-shaped blades or paddles. Just now hundreds of thousands of installations of belt-conveyors were at work on almost all kinds of material. *A belt conveyor might be described as an endless belt running over a drum at each end of the framework, with intermediate supporting rollers for both the top and bottom runs of belt.* Practically the only type which could deal successfully with gritty or hot materials was *the gravity bucket conveyor.* It might be described as *two lines of chain parallel to each other with projecting pins or axles having suspended buckets, these being maintained in a horizontal position by the action of gravity,* whatever position the line of chains was in.

An elevator was an appliance for lifting or handling material from one level to another; this need not necessarily be vertical, as the elevator could be at any angle to suit requirements. There were various designs of elevators, each having certain essential features by which they were peculiarly suitable for handling the many different kinds of material. The designs usually adopted comprised a steel-cased chain elevator, lattice-framed chain elevator, steel-cased belt elevator, lattice-framed belt elevator, a wood-cased belt elevator, and a continuous bucket elevator.

The term "elevator" as used in the United States and Canada is not applied to a conveyor operating between points at different levels, such as the Reno chain and sprocket conveyor. There is frequent confusion in terms due to an oversight of these different usages. In England, "elevator," in German "Elevator," in French "elevateur," etc., always means a conveyor of continuous motion type. In English the word "lift," in German *Aufzug* or *Fahrstuhl*, in French *l'ancenseur* or "lift," are the terms applied to a platform or cabin for freight or passengers hoisted and lowered in a vertical shaft. In North America this is termed an elevator.

The advance in rail freight rates has brought about an increase in the volume of coastwise traffic. No pier or wharf designed for the use of coastwise commerce is now considered complete where there is a change of water level without installation of mechanical means for aiding hand trucks or motor trucks up and down the ramp at low water.

On the Great Lakes there is an almost constant water level. Much package freight is now shipped on both passenger and freight steamers. As in the coastwise trade, these steamers use side ports for loading and discharging. At Duluth, Superior, Milwaukee, and other points, large quantities of mill products are shipped down the Lakes. Cargoes run

as high as 6,000 tons. Also the Hudson River lines at Albany make use of similar equipment. Still, in all side-port loading and discharging the longshoremen usually perform most of the transfer by hand truck across the gangplank without mechanical aid except where there is a low tide.

(*Brown Portable Conveyor Co.*)

FIG. 49.—Side-port transfer by means of portable conveyor.

Transfer through Hatches.—Ocean vessels load and unload through deck hatches. There are three kinds of unloading:

1. By means of the ship's tackle where there is no wharf equipment.
2. By means of the cargo mast where the ship's tackle and a wharf winch are used together.
3. By means of cranes on the wharf which do all of the work.

The economy of one over the other depends entirely upon the amount of cargo transferred between ship and wharf during the year. Each succeeding method involves greater capital investment in wharf equipment. Unless the volume of freight handled is increased, the interest and amortization of the increased investment will not be met by the saving accomplished.

1. Ship's Tackle.—All modern cargo steamers carry their own unloading machinery.

There has been a rapid development in the hoisting equipment of steamships as to the winches, masts, and gear.

The hatch masts are usually constructed to carry a cluster of booms of 5 tons lift. Certain large hatch (27 foot) vessels have also one or two 10-ton and even a 20-ton boom to each hatch. There has been an increased tendency in new vessels to build two masts connected by a bridge. This is the prevailing Shipping Board type, and although ugly, it is considered

efficient. The value of the advantage, considering its poor appearance and cost of construction, is doubtful.

Winches[1] have been increased in power and reliability. A standard equipment consists of two winches to the hatch, a right-hand and a left-hand winch, operated by one winch runner (sometimes two) standing between the winches and moving a simple steam-valve control lever up for lift and down to lower, using a powerful foot brake to hold the draft. These steam winches are usually two-cylinder, operating on a drum with an axle extension called a drum-end or "nigger-head" 16 inches in diameter. The longshoremen of New York who operate the winches—known as the deck crew—prefer to lift and lower the drafts and control the speed through the skilful tightening or loosening of two or three turns of rope around the drum-end (Fig. 50). The deck crew or gang consists of one signal man, two winch runners, two drum-end men. Deck winch capacities range from 2 to 3 tons direct lift and double (4 to 6 tons) half-speed or 8 to 12 ton at quarter-speed or 16 to 24 tons at eighth-speed, depending upon the rigging with 1, 2, 3, 4 sheave blocks.

(*Photograph by the author.*)

FIG. 50.—Electric dock winch with drum end man in operation. In this case the shore winch is operating the up-and-down fall through the block above the ship's hatch center. The next winch (behind post) is operating the burton-fall through the block of the cargo mast on shore. Upper deck Chelsea Piers, N. Y.

Electric Winches.—The advent of the motor ship has forced the introduction of electric winches. The disadvantages of the steam winch are: condensation and loss of efficiency in the steam transmission, particularly during cold weather; difficulty in keeping the steam fittings tight due to the working of the ship and the large amount of steam piping necessary to connect the engine rooms with the deck winches. The electric winch overcomes these difficulties, but at the same time the electric equipment is exposed to the danger of wetting by salt water, which is often sufficient to render them useless. There has been a tendency in motor-ship construction toward the shelter-deck type of vessel with the electric winches placed under the shelter deck and protected from damage by water while at sea. Recent types of electrical equipment are guaranteed waterproof when immersed. It is inevitable that there will be a rapid increase in the efficiency and use of electric deck winches with the rapid increase in the numbers of Diesel direct-drive and Diesel electric-drive installations.

[1] See MACELWEE and TAYLOR, "Wharf Management, Stevedoring, and Storage," Chap. VII.

The following is a statement concerning the operation of the two principal types of electric winches.[1]

The electric winch with dynamic braking and the winch with automatic mechanical braking are the two general types. Here we will find that, basing our figures on winches with a full load capacity of 5,000 pounds at a speed of 125 feet per minute, the other loadings with speeds corresponding to the characteristic curves of the motor, that the cargo handled per hour with a set of winches of each kind will be as follows:

TWO WINCHES WORKING TOGETHER ON A BURTONING SYSTEM

Loading draft, pounds	Dynamic breaking cargo per hour, tons	Mechanical braking, tons
5,000	105	135
3,750	82	105
2,500	57	74
1,250	30	41

Even though the cargo handled with the mechanical braking winch is about 30 per cent more than with the dynamic braking, the current consumed is 20 to 30 per cent less for the mechanical brake winch.

RIGS

Single Fall and Skid.—In handling cargo with ship's tackle there are two principal methods. The first is with a single fall and skid (Fig. 51). In this case the hook is thrown onto the wharf attached to the rove of the draft, and the draft dragged up an incline to the deck of the ship. When it swings across the hatch opening it is checked by a longshoreman with a rope. It is then lowered into the hold. This method is suitable only for loading, and for certain kinds of cargo. The cargo is liable to damage by this method. It is not generally used.

Burton Tackle.—The second, the burton system (also called in England the union purchase) is with an up-and-down fall running through a block in the peak of a boom fixed above the hatch, and a burton fall running through a block fixed at the peak of a second boom, swung outboard reaching past the gunwale and above the wharf. Both whips (also called falls or cables, or ropes) are attached to a single hook. In discharging, there will be the following movements: The deck winch operating the up-and-down fall will lift the draft out of the hold to above the hatch combing. At this point the winch operating the burton fall will begin pulling the load, and as the rope is wound in, the up-and-down rope is paid out until the draft crosses the deck to a position above the

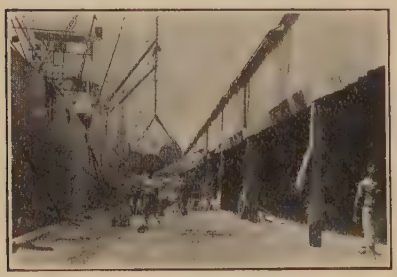
[1] FASTING, S., in the *Pacific Marine Review*.

wharf. At this point, the up-and-down fall lets go entirely and the burton fall lowers the draft to the wharf. Figs. 52, 94, 114.

(*Photograph by the author.*)

Fig. 51.—Loading ship with single fall and skid. The longshoreman on deck is ready to throw a rope around the fall and check the swing of the draft. At the Army Supply Base, Philadelphia, Pa.

2. Cargo Mast.—The American machineless unloading may be defective, but there is no room on a narrow pier for cranes. The cargo mast is



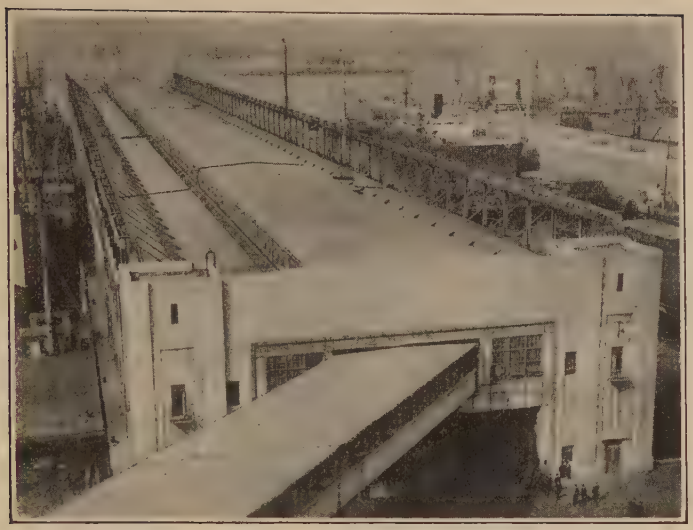
(*Photograph by the author.*)

Fig. 52.—Ship's tackle, two booms, discharging without shore equipment at a private wharf and warehouse in Havana, Cuba. This is the usual condition where ships must be self-sufficient.

(*Photograph by the author.*)

Fig. 53.—Cargo masts (Chelsea Piers, N. Y.) showing whip blocks attached by bolts and shackles to mast girders. "Cat walk" extends the length of the pier to facilitate rigging.

at a height of 75 to 80 feet above low water extend along the water's edge, a successful compromise. On the pier edge, masts carrying a girder



(*Photograph by the author.*)

FIG. 54.—Cargo mast equipment of one of three piers of the U. S. Army Supply Base, South Brooklyn, port of New York.

(*Earle, Manila, P. I.*)

FIG. 55.—Double webb slings landing nearly 2 tons of flour in bags at a single transfer. The entire draft including slings is lowered onto a platform lorry and picked up by a lift truck for immediate removal from ship's side. Discharging U. S. S. B. Steamship *President Arthur* at Pier No. 1, Manila, P. I.

A block and tackle with a line from a drum hoist on the pier to the hook is attached to this girder by a shackle bolt and stirrup (Fig. 53 and 54). A ship's boom and hoist also operate another line to the same hook, thus both ship's tackle and pier tackle work together. There are three movements, the same as just described for burtoning with two cargo masts. The movement made is without lost motion and by the shortest possible route. The cost of the installation is low, the saving in time is great. The cost of operating two hoists and two operators instead of one is greater than with the crane. The cargo mast operates at about 40 to 120 cycles an hour. This is the "first aid" where there is no room for cranes, or where the annual transfer per linear foot of wharf is not great enough to carry the overhead of full crane equipment.

Slings.—At this point, the various types of slings may be mentioned. *The simple rope sling* is made by splicing together the ends of a length of rope. This endless rope is laid on the floor of the wharf or hold; the cargo is piled on it to a convenient size or weight, usually not exceeding 1,000 or 1,500 pounds, care being taken that one end of the sling be longer than the other. The long end, called the *rove*, is then passed through the shorter end, called the *bite*, or *biglet*, which is driven down tight with a piece of dunnage or a short piece of pipe kept for this purpose. The hook is put into the rove and the draft lifted.

The web sling is a canvas covering perhaps 1½ to 3 feet wide, sewed over the sling, its purpose being to prevent the pressure of the rope cutting bags of flour, sugar, coffee, and other soft, bagged materials, by distributing this pressure over a larger surface of the draft (Fig. 55).

The *platform, tray* or "*aeroplane*" sling (Figs. 56 and 57), is used for fragile cases of uniform size, such as canned goods, eggs, crates of apples, and other fruit. It is a stout platform, through the corners of which are passed two rope loops, one longer than the other forming the rove and bite. To prevent the crushing of the cases by the ropes, angle irons with rings through which ropes are passed complete the equipment, the angle irons being fitted against the upper corners of the top cases of the draft distribute the pressure of the rope over a large surface.

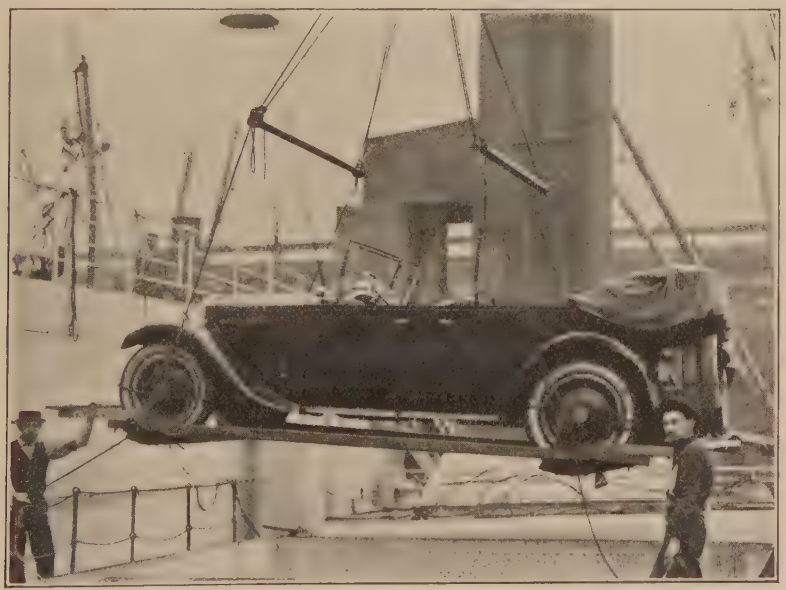
The *net sling*, as its name implies, is a rope net some 15 feet square, the opposite corners being alternately longer and shorter, in each case forming a rove and bite. The cargo to be lifted is piled in the center of the sling, the hook passed through the two roves.

Rails, structural steel, pipe, etc., are handled usually by *chain* slings, sometimes by magnets. Nails in kegs can be handled by magnets. Transferring rails by magnet is a hazard. If the current is interrupted by any accidents the rails may go through the bottom. Great care must be taken to insure continuous current.

Barrels are handled by *cant hooks*, and are usually slung "married," *i.e.*, in pairs.

(*Earle, Manila, P. I.*)

FIG. 56.—Tray or platform sling landing case goods onto a platform or bench or hand lorry that is picked up, as landed with slings attached, by a platform lift electric tractor and moved at once away from ship side to a point in the shed or to waiting drays or railway cars. Pier 7, Manila, P. I.

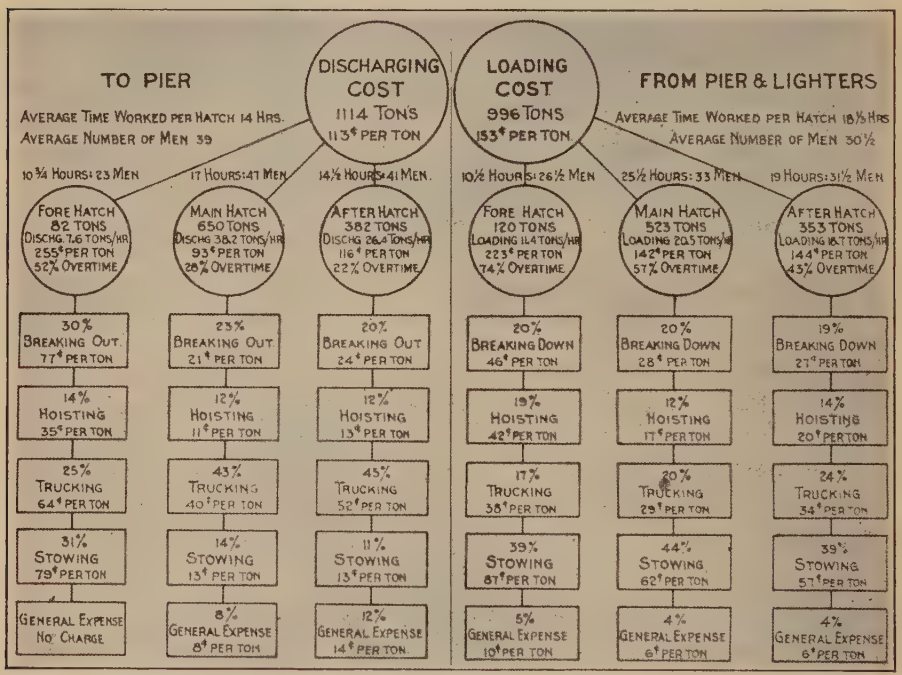


(*Courtesy of La Campagnie Général Transatlantique.*)

FIG. 57.—A modified platform sling with spreaders used in transferring uncrated automobiles. This traffic is being cultivated by passenger lines between Europe and North Amreica not alone as a service to tourists to Europe, but to utilize steerage passenger deck space now much in excess of demand.

Stevedores and longshoremen are quite ingenious in inventing special types of slings for handling unusual cargo. The above types are all used where a hook on the end of a fall is lifted by either winches or cranes.[1]

Analysis of Loading and Discharging Costs at New York. (Fig. 58).—Studies have been made of the time and cost of working a ship at New York with general cargo using ship's tackle and cargo masts. It is assumed that this case is in line with the general practice of serving the ship from the water side by lighters. More than half of the cargo would be loaded or discharged by ship's gear alone. Also this analysis was made at the peak


TO PIER
AVERAGE TIME WORKED PER HATCH 14 HRS.
AVERAGE NUMBER OF MEN 39
DISCHARGING COST
1114 TONS
113¢ PER TON
LOADING COST
996 TONS
153¢ PER TON
FROM PIER & LIGHTERS
AVERAGE TIME WORKED PER HATCH 18½ HRS
AVERAGE NUMBER OF MEN 30½
10¾ HOURS: 23 MEN
17 HOURS: 47 MEN
14½ HOURS: 41 MEN.
10½ HOURS: 26½ MEN
25½ HOURS: 33 MEN
19 HOURS: 31½ MEN
FORE HATCH 82 TONS DISCHG. 7.6 TONS/HR 255¢ PER TON 52% OVERTIME
MAIN HATCH 650 TONS DISCHG 38.2 TONS/HR 93¢ PER TON 28% OVERTIME
AFTER HATCH 382 TONS DISCHG 26.4 TONS/HR 116¢ PER TON 22% OVERTIME
FORE HATCH 120 TONS LOADING 11.4 TONS/HR 223¢ PER TON 74% OVERTIME
MAIN HATCH 523 TONS LOADING 20.5 TONS/HR 142¢ PER TON 57% OVERTIME
AFTER HATCH 353 TONS LOADING 18.7 TONS/HR 144¢ PER TON 43% OVERTIME
30% BREAKING OUT 77¢ PER TON
23% BREAKING OUT 21¢ PER TON
20% BREAKING OUT 24¢ PER TON
20% BREAKING DOWN 46¢ PER TON
20% BREAKING DOWN 28¢ PER TON
19% BREAKING DOWN 27¢ PER TON
14% HOISTING 35¢ PER TON
12% HOISTING 11¢ PER TON
12% HOISTING 13¢ PER TON
19% HOISTING 42¢ PER TON
12% HOISTING 17¢ PER TON
14% HOISTING 20¢ PER TON
25% TRUCKING 64¢ PER TON
43% TRUCKING 40¢ PER TON
45% TRUCKING 52¢ PER TON
17% TRUCKING 38¢ PER TON
20% TRUCKING 29¢ PER TON
24% TRUCKING 34¢ PER TON
31% STOWING 79¢ PER TON
14% STOWING 13¢ PER TON
11% STOWING 13¢ PER TON
39% STOWING 87¢ PER TON
44% STOWING 62¢ PER TON
39% STOWING 57¢ PER TON
GENERAL EXPENSE NO CHARGE
8% GENERAL EXPENSE 8¢ PER TON
12% GENERAL EXPENSE 14¢ PER TON
5% GENERAL EXPENSE 10¢ PER TON
4% GENERAL EXPENSE 6¢ PER TON
4% GENERAL EXPENSE 6¢ PER TON

(*From Bi-state Report. N. Y.-N. J. PDC.*)

FIG. 58.—Cost Analysis by Hatches. Discharging and loading a steamship in the port of New York, handling sugar, coffee, oil, wire, iron plates, foodstuffs, etc. Investigation made by New York, New Jersey Port and Harbor Development Commission. General expense includes cooperage, wages of cargo checkers, and special watchmen.

of wages and costs just following the Armistice. As most of the cost is due to wages, and as wages have not been reduced so much as other cost elements, these figures are not now unduly high. The studies in "Wharf Management" of this same problem showed an average of over $2 a ton for working the ship at the peak in 1920.

The point of greatest interest in the discussions in this chapter is the proportion of the total loading and discharging costs chargeable to "trans-

[1] See MACELWEE and TAYLOR, "Wharf Management, Stevedoring and Storage," p. 154.

fer." The average is 12 to 14 per cent with one instance of 19 per cent. Assuming 12 to 15 per cent of the total expense due to transfer, any large investment in wharf cranes or other mechanical transfer equipment can only be justified if the savings are very marked and the volume of tonnage handled throughout the year be very large.

These figures show that the large part of the stevedoring expense is to be laid at the door of handling and trucking, including breaking out, breaking down, stowing, and piling in hold or transit shed. In order to reduce the cost of handling and trucking to a minimum, the actual machinery for transfer, such as ship's gear, cargo mast, or wharf crane is of far less importance than the layout of the wharves with a proper interrelation in all their parts.

The cost analysis of the Bi-state Report is of great interest as a guide to such important studies.

During 1925 the entire list of port charges borne by the ship from pilotage in and out to stevedoring at one out port ranged from $1.40 to $1.80 per ton of cargo lifted. The ship was of 9,970 dwt and lifted 2,000 to 4,000 tons of general cargo, cotton predominating at each call. This was considered a fair average of South Atlantic and Gulf ports. A flat average of all cases should not exceed $1.50 per ton lifted for *all* port charges and stevedoring using ship's gear.

CRANES

The great aim in all terminal facilities is to decrease the length of time required of a ship to be in port to discharge and load cargo and to decrease the cost of handling, transfer, and stowing: increase service, decrease cost. The increase of speed of loading and discharging can be accomplished through additional numbers of longshoremen only to a certain point, because of the congestion at the two points of deposit—the points where the drafts are picked up or put down on the wharf and in the hold of the ship. Various methods are used to increase the area of the point of deposit to enable more longshoremen to work simultaneously.

It has been insistently maintained that the European ports through the use of wharf cranes have been successful in increasing the speed of the transfer movement and also increasing the working area. Formerly these cranes were hydraulic, but practically all modern installations are of the electric type. Cranes have been used in European ports for centuries.

The Old Lüneburg City Crane.[1]—There is nothing new about the use of cargo cranes. In view of the present agitation for a wider use of wharf cranes in American port development, it is interesting to note the antiquity of such

[1] MacElwee, Roy S., "An Old Crane," published as a contribution to *Dock and Harbour Authority*, March, 1924.

mechanical devices for handling cargo between ship and shore in European ports. One of the oldest large-capacity wharf cranes in existence is that at Lüneburg, Province of Hanover, Germany.

The writer discovered this old crane by accident in the spring of 1913, while on a week-end canoe trip from Hamburg[1] down the Ilmenau, a picturesque stream tributary to the River Elbe, above Hamburg, winding its course through the

(*Photograph by the author, June*, 1914.)

FIG. 59.—Old public wharf crane, Lüneburg (Province of Hanover) as it stands since 1797, and on this spot since before A. D. 1340.

section of the Province of Hanover known as the Lüneburger Heide. The half-way point of a lazy paddle is the very old city of Lüneburg. This city reached a high position of commercial dominance in the Hanseatic League in the fourteenth century, and maintained its dwindling importance through slow centuries of decline.

The principal articles of commerce throughout the Middle Ages were salt and herring. The predecessor of the present Exchange was called Herring House, *domus allecium*, *haringhus*. The "new" structure, a delightful example of northern Baroque, was built between 1741 and 1745. It is a charming type of the simpler Renaissance decline.

[1] By rail from Hamburg to head of river.

But the principal object of interest was the old crane. As a youthful salesman of elevators and conveyors, the writer had little interest in antiques and was unable to find out much about it at the time. Only after the war, when communication with Germany became possible, correspondence with Prof. Dr. W. Beinecke, City Librarian, Lüneburg, and Dr. F. Havemann, City Engineer of Lüneburg, to whom we are indebted for the research, made it possible to describe both the history and the mechanical construction of this interesting piece of pioneer harbor machinery.

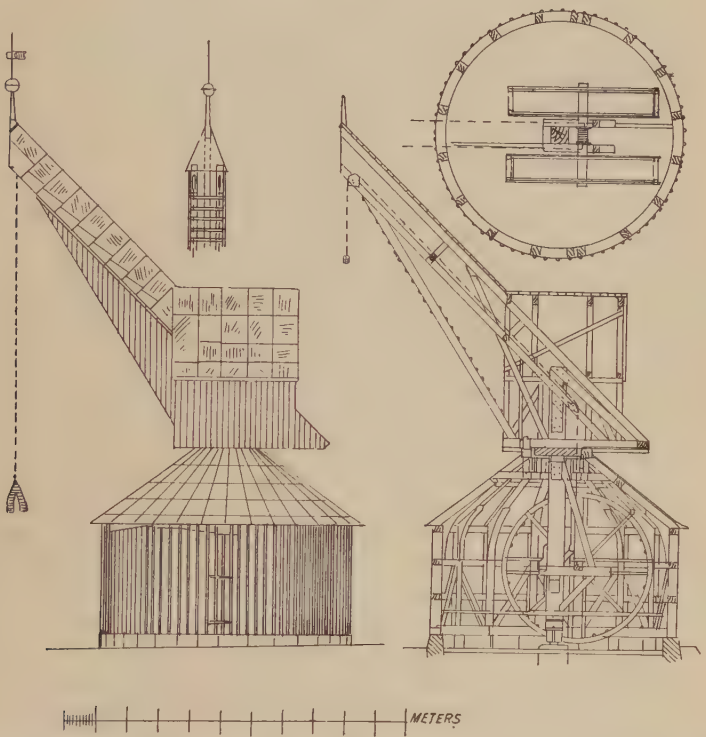


FIG. 60.—Old Town Crane, Lüneburg. Drawings by F. Havemann, City Engineer, for a 1/15-size working model in Lüneburg City Museum.

It is evidently the oldest existing harbor crane of large type. A similar crane stood in Bruges in Flanders until modern times, but disappeared some 15 or 20 years ago. Old pictures of the sugar boiler section of Hamburg, now occupied by the Freeport Warehouse Company, showed rows of small hand cranes used in handling colonial sugar from lighters to the quays. However, as far as is known, the great Municipal Crane of Lüneburg is not only the largest crane of its time, but is the only example extant. It is not used, but is in perfect condition and could be operated as readily as at the time it was last overhauled, which was about the time the Constitution of the United States was being written.

The crane now stands as remodeled and repaired by G. P. Hintze, and turned over to the city on Aug. 26, 1797, according to a plate carved in wood in the

interior of the housing. A public crane, however, existed on this site since earliest times. One of the first references to the crane states: *Prope aguam; ultra aguam Elmenov inxta cran civitatis*, which, translated, means, "On the water, or at the water, on the other side of the River Ilmenau by the City Crane." This reference is in an old work describing the location of a street. Another reference, in 1361, reads: *Prope aguam fluvialem que Elmenov dicitur ex opposito ipsius instrumenti quod cran nominatur*—"At the waters of the river called the Ilmenau exactly opposite the instrument which is called the crane." In the same year in another place: *Prope Elmenomve ex opposito cran*—"Near the Ilmenau opposite the crane." There is a record of payments made by one Werneke von Bardwik in 1330, for the use of the crane and the Herring House (the ending *wik* is characteristic of proper names and many nouns in the low countries inhabited by the Wends during the Dark and Middle Ages). There is also a record in 1372 showing that the Senate mortgaged the crane and the Herring House. The Senate paid off the mortgage in 1410. Street pavers are noted in the city records as having worked *bei dem krane*, and in 1430, 120 cut stones were landed *bei dem krane*. There is a record that in 1438 workmen repaired the crane; in fact, the City Council, or Senate, voted money almost every year toward the maintenance of the City Crane, and it is mentioned in the records throughout the centuries. In the old tax lists, for instance, in 1484, the street called *Amfischmarkte* (Fish Market) was known as *Achter dem krane* (behind the crane). The town council passed a law in 1346 to the effect that it was forbidden for the house facing the City Crane to be used as a warehouse for salt or herring.

The crane was entirely rebuilt in 1482, when 6,000 bricks and 126 pounds of lead were used, evidently for the counterweight: *lodinge des steynen hovedes*. Also in 1537 the *mole mester* (quay master or wharfinger), named Hinrick, rebuilt the crane according to a new system, placing it on four large iron plates. He roofed the tower and the crane arm with copper, and the circular house was weighted with lead.

The present crane, rebuilt in 1797, is a very interesting piece of machinery. Doubtless there was little change in the general appearance of the crane from that of much earlier times, as crane engineering then, as now, followed certain general forms. A miniature illuminating the "Hamburg Law Book," 1497, which begins with the Shipping Laws, shows a harbor scene with a similar crane to this one in Lüneburg.

Construction and Operation.—The entire crane is built around a vertical shaft, which carries the mechanism for winding up the chain and hook to lift the draft of cargo—the up and down whip or fall—and for racking or revolving the boom. The main crane house that serves to protect the mechanism is circular in form and has an outside diameter of 8 meters. The vertical shaft of oak in the center is 58 centimeters in diameter and 9 meters, 20 centimeters high. Attached to the vertical shaft on the ground floor is a horizontal shaft of 28 centimeters in diameter, with a drum in the middle for winding up the chain. It carries on each end a large wheel, 5 meters in diameter, fitted with slats and operated as a treadmill. Between the two treadmills a ladder extends to the upper crane house. This contains the blocks, or rollers, over which the chain runs to the end of the crane arm, or boom. Slats inside the crane boom permit the workmen to reach the highest point or peak of the boom. The entire crane arm and

upper crane house with its rollers are firmly attached to the vertical shaft of oak. The weight of the upper crane house and boom rests on a bronze plate braced by angle irons to the vertical shaft at the truncation of the conical roof of the main crane house. The foot of the vertical shaft turns on four wheels on an iron plate. The vertical position is maintained by means of the framework of the main crane house, which acts as a brace against the bronze plate and transmits the thrusts of the upset movement from the bronze plate through the framework to the ground. The boom is racked or revolved by turning the vertical shaft with capstan-bars, the men walking around the circular way, set with cleats, inside the round crane house.

The crane is operated as follows: When a load is to be lifted, one or two men enter each of the large wheels and start walking like a squirrel in a cage. If the weight is heavy, additional men outside the wheels help along by grasping the rim of the wheels or the spokes. In this manner the chain is wound around the drum and the weight lifted. When the load is clear a ratchet locks the drum, the workmen come out of the wheels and, grasping the capstan arms, walk around the inside of the crane house and rack the crane arm by revolving the vertical shaft. To lower the load, the ratchet is removed and the load allowed to drop by gravity, applying such force as necessary to the treadmill wheels to break the fall. It will be seen that the same lifting, lowering, and racking movements of a modern electric wharf crane were accomplished by this pioneer, and for loads of considerable weight, perhaps 2 to 3 tons, by using man power. Labor was cheap in those days.

In Danzig a crane on the Long Bridge dates from 1410 A. D. It is more of a bridge or gateway structure, a gantry or portal crane.[1]

In connection with the old Lüneburg crane, it may be added that this crane and its predecessors on the same spot, mentioned in documents 150 years before Columbus discovered America, were quite recent, as cranes go. According to descriptions of Vitruvius, Chap. II, of the Tenth Book, various types of cranes were known to the Romans in building construction. Some of these building cranes in Rome were of large dimensions and were operated by treadmills, as shown in a relief in the Lateran Museum in Rome, according to Blummer, Technologie, page 119, Book 3, published in 1884.

In the Middle Ages one often finds the type of revolving crane built about a vertical column, operated by a treadmill and racked or revolved through a complete or an almost complete circle. One of the first authentic representations of such a crane is found on page 28,710 of the famous Heidelberg Minnesenger manuscript of the year 1310 in the University Library of Heidelberg. The first technical description of building cranes is found in the Court Library of Munich, from the pen of *Anonymus der Hussitenkriege* (Anonymous, of the Hussite Wars). Eight cranes are described, one of which served for wrecking buildings, lowering cut stone, while the others were used for building construction. In his book "Beiträge zur Geschichte des Maschainenbaus" (Contributions to the History of Machine Construction), 1900, page 270, Theodore Beck shows with what simple means men lifted heavy packages, even as late as the fifteenth century. In the illuminated manuscripts of the fifteenth and six-

[1] Photograph reproduced in Heinrich Bergner, "Handbuch der Kunstaltertume in Deutschland," 1906. No. 358.

teenth centuries there are comparatively few pictures of building cranes. There are, however, a number of wood cuts and copper etchings which show revolving cranes used in the construction of churches and cloisters.

Leonardo's Elevator.—In 1500 Leonardo da Vinci designed a huge crane to be used in his canal project.[1] He also designed a unique elevator for the rapid hoisting of building and other materials. It consisted of a two-platform, reciprocating elevator. When the one platform was down being loaded the other platform was at the top of the tower. This upper platform was reached by a ramp. A driver with an heavy ox would ride up the ramp and onto the upper platform. The weight of the ox and his driver, being greater than the weight of the load, would hoist the load. In the process the ox and his driver would find themselves again on *terra firma*, ready to climb the ramp again. This type of two-platform elevator, operated by the weight of an ox, was actually introduced and tried out in 1835 by the mathematician Coulomb and the engineer Coiquet.

In 1629, according to Branca, Book C, plate 21, a building construction elevator was built on the principle of the treadmill and drum, with a reversing clutch, and raised by means of large, alternating platforms.

Great advances were made with the invention of hydraulic and steam cranes, but it remained for modern engineers with the aid of electricity to build the highly efficient rigs for handling materials that we now know in every type of industry and commerce—from Huelett unloaders that take 20 tons of ore at a grab, to the express elevators of the Woolworth Building. Nevertheless, the principle involved in the old City Crane of Lüneburg, 150 years before Columbus discovered America, is only now beginning to be adopted in American port development; that is, the public wharf and public warehouse and the public wharf crane for the use of all shippers upon payment of a small fee established by a tariff.

CRANE TYPES

Not only transfer between ship and wharf, but every type of heavy lifting requires some sort of assistance to man power. There are various standard types of cranes and derricks that should be thoroughly understood. It is therefore necessary at this point to pass in review these outstanding types in order to have clear mental pictures and exact terminology for further discussion.[2]

A timber stiff-leg derrick is the simplest form of hoisting machine. It is often used in building construction and derived its name from a vertical leg held in position by two anchored, supporting, bracing timbers. At the foot of the leg is stepped a boom on some sort of universal joint to permit its movement in any direction. The peak of the boom is connected to the top of the mast or stiff-leg by a block and tackle, which controls the angle of elevation of the boom. From the peak of the boom is suspended a

[1] FELDHAUS, "Leonardo," plates 2 and 3.

[2] See MACELWEE and TAYLOR, "Wharf Management, Stevedoring and Storage." These are fully illustrated in Chap. X.

block and tackle, double or triple, with a free pulley carrying the hook, the rope being passed through pulleys in the boom and at the foot of the stiff-leg to the driving mechanism, which may have as motive power steam, electric, or gas winch or even an old mule. At the Smith's Cove

FIG. 61.—Seventy-five-ton Shear Leg Derrick—Smith's Cove Terminal, Seattle, Wash.

Pier, Seattle, is installed a large *shear-leg* derrick. The essential difference between the stiff-leg and the shear-leg is, the stiff-leg derrick has a fixed angle mast (vertical member) with fixed or stiff oblique bracing members; this requires a boom for luffing and racking. A shear-leg derrick has a double mast spread at the bottom like a pair of scissors with the blades of the scissors spread somewhat, and the two points stuck into the ground and hinged with the diagonal member movable so as to rack the masts backwards and forwards. If you tie them together with cross-braces, and fix the stiff-legs, you have an A-frame, but this requires a boom (Fig. 61).

1. The *Smith's Cove shear-leg* installation has a 75-foot steel boom with 125-tons lifting capacity, and costs $25,000. A 75-foot wooden shear-leg derrick was installed at Salmon Bay at a cost of $19,000.

2. *The A-frame derrick* is similar to a stiff-leg derrick. There are two vertical members joined together by cross-braces similar to the letter A, held in position by struts and operating a boom similar to the stiff-leg. This type is used most frequently on lighters.

3. The *guy derrick* is similar to the stiff-leg, but the vertical member or mast is held in place by the guy ropes attached to a spider plate and shackles fixed to the masthead top iron. These guy ropes are anchored at a convenient distance to give vertical rigidity to the mast. This type of derrick is used for temporary work, such as erection of buildings. The usual type has a 90-foot boom of steel structure. It may be quickly rigged temporarily for any job where there is open space, and is a convenient piece of equipment to have at any port.

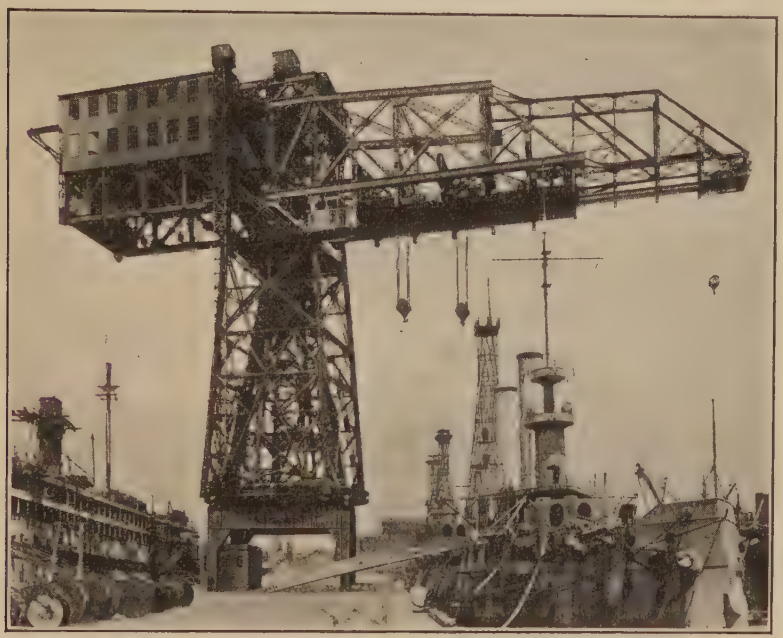
4. The *locomotive crane*, as the name implies, is a steam crane mounted on standard gage railroad trucks, and can move along over standard tracks similar to a locomotive. Locomotive cranes are usually used for heavy duty, lifting from 10 to 50 tons. The boom, from 40 to 60 feet in length, is hinged, and may be lifted and lowered, *i.e.*, luffed. It may be slued, *i.e.*, moved sidewise or racked. Also the entire mechanism may be constructed to be revolved on a circular track base. A locomotive crane may be fitted with a hook with an electric magnet or with any type of bucket—clamshell, orange-peel, etc. The advantage of the locomotive crane is its mobility and versatility. It is particularly useful in handling materials in open storage. However, because it is so short of stature it cannot reach over the sides of vessels except those with low freeboards and setting low in the water.

5. A *tower crane* is any type of lifting device mounted on a tower. Also vertical member or mast that carries the luffing tackle is usually a short triangular or four-sided lattice steel pyramid tower. The boom is usually similar to that of a locomotive crane or guy derrick—a luffing and racking boom. The crane may revolve upon the supporting tower, in which case it becomes a *traveling revolving tower crane.* Revolving tower cranes are frequent in shipyard equipment.

6. *Hammerhead Crane.*—For extra-heavy duty, the tower crane is supplanted by the hammerhead crane, used usually in fitting out basins of shipyards and navy yards. The hammerhead crane is a horizontal bridge cantilever construction supported on a steel tower. The cantilever arm has its weight and a percentage of the maximum load counterbalanced by heavy counterweights of concrete or cast iron. This solid block of counterweight gives it the appearance of a hammer, from which it derives its name. When the members of the American Engineering Society visited Europe in 1913, they inspected what was then the largest crane in the world of the hammerhead type at the Blohm and Voss yards at Hamburg, where the *Leviathan* and the *Majestic* were constructed, and fitted out under this crane. It had a lifting capacity of 250 tons.

Blohm and Voss 250-ton Crane.—In the design of this crane great care was taken to reduce the deadweight to the utmost so that the crane could be worked with the least power possible. Owing to the great many ways the load may be applied in addition to the numerous motions that had to be performed the calculations were of a most elaborate nature. The whole crane, and especially the jib, were built to offer the least possible resistance to wind pressure.

The crane is capable of lifting a load of 250 tons at a radius of 113 feet; 200 tons at 130 feet; and 100 tons at 175 feet. The electric locomotive crane, that



(*Courtesy of McMyler Interstate Company.*)

FIG. 62.—A 350-ton Hammerhead crane, Philadelphia Navy Yard.

travels a distance of 300 feet on the top of the cantilever, is able to lift 20 tons at a radius of 33 feet, and 10 tons at 60 feet, so that the total radius for a 10-ton load is not less than 240 feet.

Since then, engineers in the United States have built several of this size and one with a capacity of 350 tons. The latter is located at the League Island Navy Yard, Philadelphia, at a cost of $875,000 (Fig. 62).

A very vivid idea of the size of this structure is given by considering the dimensions of the machinery house, which in itself is a large building 80 feet long, 43 feet wide, and 32 feet high. A ten-story building could be placed under the jib of this crane, and its overall height is above 245 feet, or about that of a 17-story building.

This crane has a capacity of 350 gross tons, or 392 net tons, and is probably the largest capacity crane, of any description, which has ever been built.

A book might be written on the design of this machine alone. However, space will permit only a brief description and an outline of the possibilities of the crane.

Unlike the smaller capacity "Hammerhead," the revolving portion of this crane is supported by a structural steel octagonal pillar. This pillar tapers gradually from the bottom to the top and forms a support for the roller bearing which carries all of the rotating parts of the crane.

The revolving portion of the crane consists of a horizontal truss, the front portion of which supports the trackways carrying the main and auxiliary trolleys. The rear portion of the truss supports the machinery as well as the counterweight. The truss maintains its horizontal position by means of a structural steel frame or apron which encircles the pillar and extends down to a point near the portal. Steel rollers are mounted in a flexible pin-connected band at the bottom of the apron and come in contact with an annular roller path on the pillar.

The crane is equipped with two distinct main hoist units, each having a separate hoisting and trolley racking mechanism. Each main hoist has a maximum capacity of 175 gross tons and may be operated separately. To develop the maximum capacity of 350 gross tons the two main hoists are operated jointly, as a single unit through a mechanical and electrical coupling device.

The machinery house on the rear cantilever is fitted with a crane runway 42 feet centers. This crane runway supports a 35-ton electrically operated, overhead traveling crane for handling the operating mechanism of the shipbuilding crane when necessary. The crane runway extends over the end of the rear cantilever, which enables the overhead traveling crane to raise or lower machinery parts.

A feature of considerable engineering interest is the electrical equipment, especially as regards the control devices for various operations, providing every possible safeguard.

The contract for this crane was awarded by the United States Government strictly on the merit of design. The bid for this design was the highest submitted.

The following speeds, capacities, and reach feature this crane:[1]

Capacity

Each main hoist..... 115-foot radius, 175 gross tons
Both main hoists, acting as a single unit..... 115-foot radius, 350 gross tons
Two 8-part lines are used on each main hoist, 32-part line being used to make the maximum lift of 350 gross tons.
Auxiliary hoist..... 190-foot radius, 50 gross tons
The load is handled on two 4-part lines.
Maximum operating radius, each main hoist..... 115 feet
Minimum operating radius, each main hoist..... 41 feet
Maximum operating radius, both main hoists operating as a single unit..... 115 feet
Minimum operating radius, both main hoists operating as a single unit..... 41 feet
Maximum operating radius, auxiliary hoist..... 190 feet
Minimum operating radius, auxiliary hoist..... 41 feet

[1] The McMyler Interstate Company.

Hoisting speed in feet per minute

Both main hoists, operating singly or jointly, maximum load	2.5 feet
Both main hoists, operating singly or jointly, no load	10 feet
Auxiliary hoist, maximum load	12 feet
Auxiliary hoist, no load	30 feet

Sluing Speed

One revolution in 12 minutes.

Trolley racking speed in feet per minute

Both main hoists, singly or jointly, maximum load	12 feet
Both main hoists, singly or jointly, no load	100 feet
Auxiliary hoist, maximum load	100 feet
Auxiliary hoist, no load	150 feet

7. *Pontoon Crane.*—Any crane mounted on a float or lighter, or pontoon, comes under this category and is listed under *floating equipment.* Heavy lifts are handled better from lighters by heavy duty derricks or cranes than over a general merchandise wharf. One of the largest pontoon cranes built to date is at the Portsmouth Navy Yard, Virginia (constructed by the Wellman-Seaver-Morgan Company) (Fig. 63).

(*Photograph by the author.*)

FIG. 63.—Great Floating crane at the Portsmouth Navy Yard. A luffing-jib, revolving, pontoon crane of 150 tons capacity. Built by the Wellman-Seaver-Morgan Company.

The cranes are designed to lift 150 tons at a radius of 105 feet and at a speed of 4 feet per minute with a vertical range from 25 feet below to 95 feet above the level of the water. The main hoist is comprised of two separate units of 75-tons capacity each and the hook blocks, being suspended from a fixed position on the jib, are arranged to be connected together when handling 150 tons.

A 25-ton capacity hook block is suspended on a trolley which travels along the under side of the jib. This hoist has a vertical range from 25 feet below to 130 feet above the surface of the water and hoists 25 tons at a speed of 12 feet per minute or 5 tons at 60 feet per minute. The jib, carrying the maximum load, is luffed from its lower position to the highest point in 15 minutes, and in the reverse direction in about 11 minutes. A complete rotation of 360 degrees under full load conditions requires between 4 and 5 minutes.

The pontoon which forms the support for the superstructure is steel, 140 feet long, 85 feet wide, and 15 feet deep. Full depth collision compartments entirely surround the pontoon, the interior of which is provided with longitudinal and transverse bulkheads. Compartments for the boiler plant and generating unit are provided in the after end, and have an open hatchway covered by a deck house. One end of this deck house is enclosed and used as an office.

The crane superstructure is located on the longitudinal center line of the pontoon 42 feet from the forward end. A fixed tower, 43 feet high, is secured

to six bulkhead plates extending through the deck of the pontoon, and surrounds the pintle section of the rotating structure.

The three sections of this rotating structure may be designated as the pintle section, the machinery section, and the jib. The pintle section rests on a heavy step bearing attached to the deck, and extends above the top of the fixed tower, within which it rotates. The jib is hinged to the front side of the pintle section 60 feet above the deck and the rear side is extended to form a support for the machinery section in which all of the operating units are located.

All of the motions of the crane are controlled from the operator's cab, which is located on the rotating structure just below and to the right side of the jib hinge pin.

The jib is luffed by a screw-operated crosshead which travels in vertical guides at the rear of the machinery section and is connected to the upper chord of the jib by heavy links. The jib is approximately 125 feet long, and, when in its upper position, the total height is 190 feet above the water. Four electrically driven capstans are located near the corners of the pontoon. The equipment also includes two steam-driven windlasses.

8. *Goose-neck crane* is one frequently found in floating equipment and consists of a slanting mast to which is given a greater angle of inclination from the perpendicular near the peak. Upon analysis, it is a "leaning-tower" crane, with a fixed jib. This type is used with a clamshell or orange-peel bucket. It is used most frequently in bunkering coal-burning ships. The port of Havre, France, has 150 pontoon goose-neck cranes used for bunkering coal and for general cargo transfer with the ship brested off from the wharf to admit the equipment.

9. *Gantry Crane.*—The most important type of crane used in wharf equipment is some form of the gantry variety. These are called *gantry cranes* because the crane mechanism is mounted on a gantry. The word *gantry* means to span, and the gantry is any form of structure that spans. The type of gantry gives its name to the crane, as well as the type of the crane itself. The usual gantry jib crane used in port terminal work may be called by various names, such as "wharf crane," "dock side crane."

The *full-arch gantry*, or *portal crane*, as its name implies, has all legs on the ground, and runs on two tracks in the same plane. These are illustrated by the photographs at Para, Brazil; Antwerp, and many other ports illustrated in this book.

Semiportal, or *half-arch* gantry has one leg on a track and on the wharf, and the inshore end of the gantry travels on a rail built into the front of the wharf shed. The accompanying illustrations of Hamburg, Bremen, Galveston, and the Boston Army Supply Base show this type.

Types of Cranes Mounted on Gantries.—The crane mechanism is usually of the revolving or rotating or full-circle slueing type, all terms meaning the same thing. Sometimes they are called twirlers. The crane can rotate or slue in either direction in a full circle on a circular track rail.

(*Courtesy Wellman-Seaver-Morgan Company.*)

FIG. 64*A*.—Inside of machinery house looking toward operator's cab.

FIG. 64*B*.—View inside of operator's cab.

FIG. 64*C*.—Machine house from operator's cab.

Wharf crane close-ups. 5,000–8,000-pound semi-portal wharf cranes. Built for U. S. Army Supply Base, Boston, Mass.

There are two distinct types of jibs, or booms: the *cantilever* type, either fixed, as in the case of the big hammerhead crane at Philadelphia, or moved by jack screws as in the case of the pontoon crane at Norfolk; and the *boom* type, with a boom similar to that of a guy derrick in which the boom is luffed, that is, lowered or raised by blocks and cables.

The cantilever type of boom may be fixed or movable. The movable jib of the cable type is illustrated by the cranes at the Boston Army Supply Base, or the Galveston type. The fixed boom is shown in the illustrations of Hamburg.

Light Duty and Heavy Duty.—Wharf cranes for general cargo should not have a greater capacity than 3 tons, and many engineers prescribe

(Photograph by C. B. Menzel, Supercargo. U. S. S. B. Steamship Opequan.

FIG. 65.—Two wharf cranes transferring a heavy lift using a balancing yoke on the hook, Para, Brazil.

a 1½-ton crane. The continual starting and stopping of a wharf crane requires much electricity to start and much wear and tear on the brakes to stop the heavy mass of a crane built for heavy lifts. As general cargo is handled in slings of seldom more than 1,000 to 2,000 pounds, a 2-ton crane should be sufficient for rapid work in transferring general cargo. The fine art in crane structure is to build the crane with all its members

of such a static perfection that there is not a point carrying excess material for the designed duty. The great difficulty in the United States is the tendency of the longshoremen and crane operators to abuse the crane attempting to lift more than the designed capacity, and by sudden starts and stops.

Considerable lifts may be managed by fast, light-duty, wharf cranes by hitching two together with union purchase. Figure 65 is a photograph of such a two-crane transfer of a crated motor truck at Para, Brazil, South America, with balancing sling yoke.

Heavy Duty Cranes.—Heavy duty cranes are essential to every port for general use or in connection with a special service. The practice at Hamburg is to place a heavy duty crane at the end of each length of

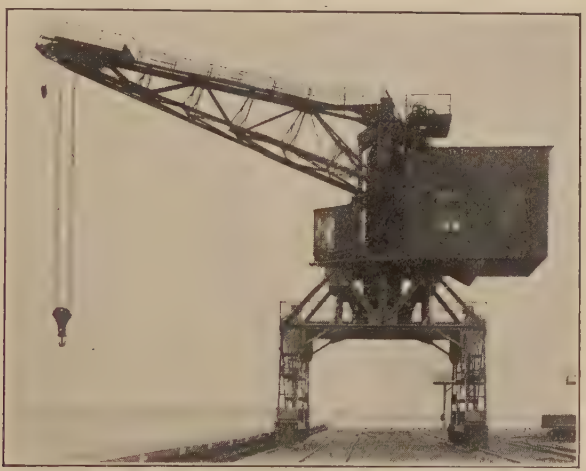


FIG. 66.—Fifty-ton, heavy-duty, full portal, gantry, revolving, luffing jib, traveling crane with 50-inch radius at the Baldwin Locomotive Works, Philadelphia. This rig loads locomotives assembled, such as the "Pershing" type for the A. E. F.

quay. Such cranes are found at the Erie wharves in Weehawken, New Jersey, at the Baldwin Locomotive Works (Fig. 66), and elsewhere. The crane is mounted on an open wharf, with railroad tracks. Ships are either brought to the wharf for loading, or the heavy drafts are transferred to a lighter, and with a floating derrick of large capacity are towed alongside the ship at its berth. In loading a vessel, the stevedore should be able to marshal all his cargo, small and large packages, so as to attain maximum stowage efficiency and speed. Shifting ship for heavy drafts will not help.

The four heavy duty cranes of the Erie Pier, Weehawken, New Jersey, are typical of heavy duty wharf cranes, on an open wharf used to transfer heavy packages from railroad cars—flat or gondola—to lighter to be towed alongside the ship at her berth.

The new cranes are capable of four distinct movements, all or any of which can be made simultaneously, as follows:

1. The main hoist motor can lift a piece of heavy package freight vertically.

2. The travel motor is capable of moving the crane longitudinally down the pier.

3. The swivel motor can rotate the boom.

4. The luffing motor is so arranged that the boom can be raised until it is almost vertical, thus clearing the masts or funnels of vessels and at the same time shortening the reach of the crane.

For example, a crated automobile truck delivered to the pier on a flat car, on any one of the five tracks, can be reached by any one of the four cranes. It could be lifted off the car, carried any distance up the pier, swung around and placed in the hold or on the deck of a vessel lying alongside the pier, whether the hatchway opening is on the near or the far side of the center line of the ship.

The equipment also includes some electric magnets. These magnets are carried by the main hoist hook, suspended from the end of the boom. In the case of unloading a car of steel billets the magnet is lowered into the car. When it comes in contact with the billets, electric current is supplied through a suitable flexible cable, with the result that when the magnet is lifted several tons of billets adhere to the face of it, and are securely held in that position until the current is shut off.

Three of the cranes have a normal capacity of lifting 10 tons at the outer end of the 50-foot boom, and they can easily handle 25 per cent overload. These cranes have a main hoist speed of 220 feet per minute; a slueing or swinging speed of three complete revolutions per minute, and they can travel up and down the pier at a rate of 150 feet per minute.

The fourth crane has a normal capacity of 20 tons on the main hoist and 5 tons on the auxiliary hoist. The speed of the former is 55 feet per minute, and of the latter 220 feet per minute.

The slueing motion is such that two complete revolutions can be accomplished in 1 minute, and this crane travels along the pier at the rate of 100 feet per minute. The wheel base of all cranes is 28 feet, and each crane spans two standard gage tracks, the gage of the gantry rails being 28 feet. In all cranes the hook lift distance is 90 feet; that is, from a position 30 feet below the rails to a point 60 feet above the rails.

London Type of Wharf Crane.—The port of London authorities comparatively recently installed fifty-six wharf cranes of a type that differs radically from the German, French, and American products. These 3-ton luffing jib cranes, with 65 feet maximum radius, are mounted on a traveling tower gantry. In other words, the circular track on which the crane revolves is two or three stories higher above the wharf than in the usual American and other portal or semiportal gantry types. A further

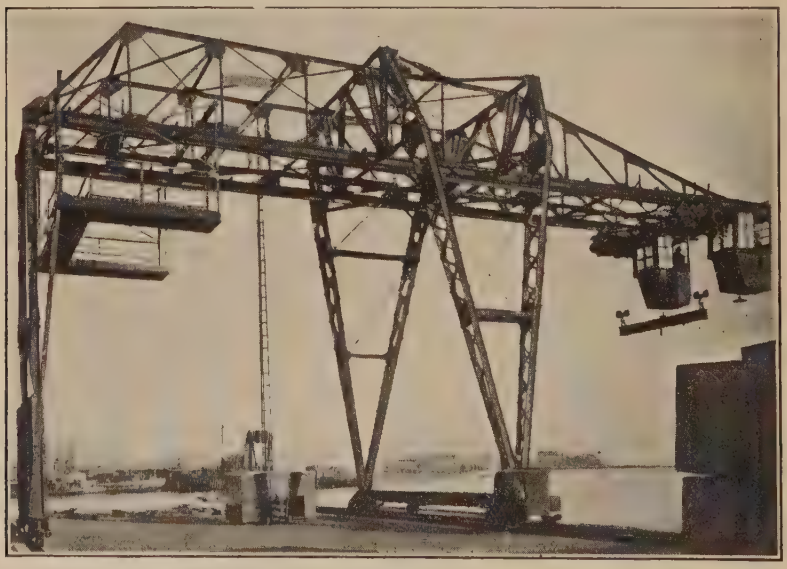
special innovation is that the end of the boom is hinged with a movable gooseneck called a "lever balanced luffing gear." Manufacturers of hoisting machinery in England put out various modifications of this luffing jib, peak type of dockside crane. The object of the jib extension or movable peak is to give a greater outreach, a smaller working space, a more positive straight-line motion, less mass to start and stop. The high tower gantry is a development resulting from the increased size of vessels and towering freeboard[1] (Figs. 67, 68).

FIG. 67.—Port of London Authority. North side of Royal Albert Dock, Royal Albert Dock Basin, and Tilbury Docks. Fifty-six Babcock & Wilcox, 3-ton, electric portal, jib cranes fitted with patent lever balanced luffing gear.

Bridge Crane.—The typical bridge crane is found at the coal and storage piles on the Great Lakes, and is usually associated almost entirely with that kind of work. This rig, however, is very well adapted to ship loading. The port of Seattle at Smith's Cove Pier has a bridge crane. It is called in various articles a gantry crane, which term is confusing, as spans of 100 to 500 feet are usually termed *bridge cranes.* This installation cost $60,000. It has a 325-horsepower motor to move the structure

[1] See CUNNINGHAM, "Cargo Handling at Ports."

FIG. 68.—Three-ton electric jib crane, 65 foot maximum radius, fitted with patent luffing gear. One of an order of 56 similar cranes for London docks.



(*Courtesy Brown Hoisting Machinery Company.*)

FIG. 69.—A traveling bridge crane with two trolleys —straight-line tracks at the 125th Street pier, East River, of the Pennsylvania R. R. Co., port of New York.

laterally along the wharf and to operate the various traveling hooks. In this manner the traveler or trolley covers a wharf area 200 feet wide by 1,000 feet in length. It serves the uncovered storage space and car tracks on the pier. The hinged boom when lowered extends 40 feet over the channel. The crane has handled as much as 110 tons of knockdown box cars an hour, transferring from car or wharf deck to the vessel's hold. This piece of equipment has been so successful that two contracts were let for two additional units of 12½-tons capacity, at a cost of $90,000 per unit.

The open wharf space of the Boston Army Supply Base is illustrative of the uncovered quay or wharf deck spanned by a bridge crane, capable of picking up heavy pieces of material, such as bridge girders, railroad

(*Courtesy, Manning, Maxwel., and Moore.*)

FIG. 70.—Straight-line roof crane at New York Barge Canal Terminal, Pier 6, East River, New York.

supplies, crated automobiles, etc., from the flat car of the wharf deck and transferring them quickly to the hold. This bridge crane was never installed at the Boston Base.

A very graceful and efficient bridge crane was installed in the East Harbor of Berlin for transferring bricks, in unit containers weighing 7 tons, from river barges to waiting railroad cars. The total span of this bridge crane was 62.9 meters, or approximately 200 feet. For heavy work on rough materials capable of being stowed in the open, the bridge crane with capacity of 7½ to 15 tons should become a very useful unit of equipment of any port.

Straight-line Crane.—Bridge cranes are *straight-line* cranes for heavy duty. There are also straight-line cranes for light duty, the most conspicuous example of which is the installation at Pier 6, East River, New York (Fig. 70), at the Barge Canal Terminal. It is called *straight-line* crane because the draft is not swung through an arc of a circle by revolving the entire crane, but the crane bearing a track remains stationary and horizontal, the only traveling mechanism being a car or trolley carrying a hoisting mechanism and hook that travels backward and forward on the track, quite similar to the movement of the trolley and hook in a *shop crane.* It will be seen that much less energy is required to move the trolley than is consumed in the revolving cranes for starting and braking. The installation in question has an outboard reach of the boom of 32 feet 6 inches and an inboard reach of 10 feet. The crane arm or boom is pivoted to a frame that travels along a track on the roof. The boom can be hoisted to a near vertical position, and then travels on the rails located above the boom to the point desired. In addition to the advantage of a direct positive movement of the hook, the draft can travel to or fro within the shed.

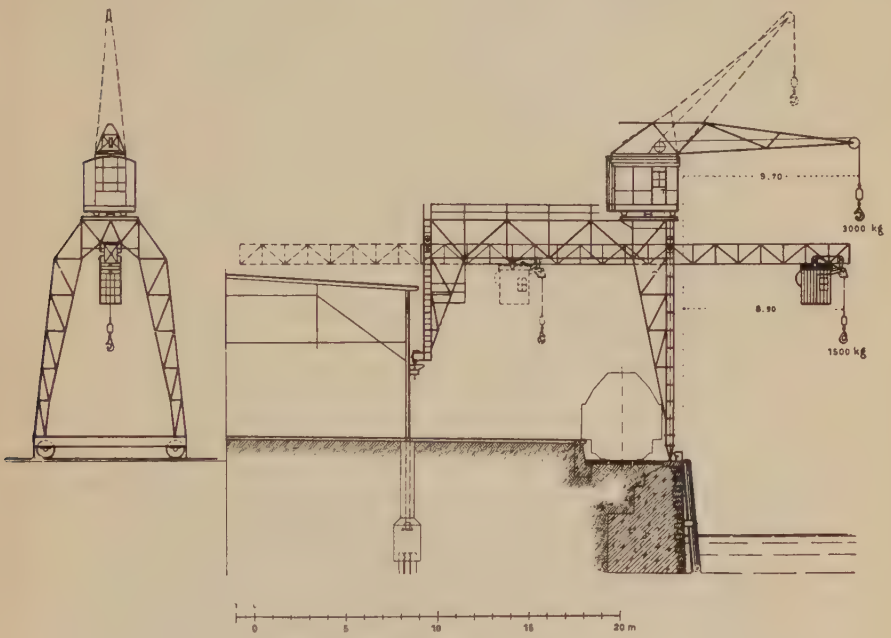
Roof Cranes.—Light-duty cranes of the usual luffing or revolving types are frequently mounted on the roof of the warehouse or transit shed in Europe, particularly in English harbors, but are not common in the United States or elsewhere.

Double or Combination Straight-line and Revolving Jib Types of Wharf Cranes (Fig. 71).[1]—Double cranes of novel design have recently been installed at the port of Hamburg, Germany. They are a combination of a traveling revolving crane on a high superstructure and a straight-line crane or transporter. To meet local conditions four combinations have been evolved.

Originally the crab of the straight-line crane accompanied the load and carried the winding gear as well as the cabin with the man manipulating the winch (Fig. 71). In later designs a fixed winch located on the gantry is preferred, the operator having his stand on one of the gantry legs from where he can overlook the hold as well as the movements of the load on its way into the shed. The runway of this type of cranes can be less substantial, a valuable feature if the reach has to be considerable. In a third design the jib of the revolving crane forms a runway for a second grab. It can be lowered so far that the load may be transported horizontally, thus forming a second straight-line crane that can be turned in a convenient angle to the pier. In some cases a combination of two revolving cranes and one straight-line crane is desired. The revolving cranes are placed on each side of the runway girder in such a way that three cranes can work over one hatch. The runway girder is designed so that it can be drawn in behind the edge of the pier. If the reach is large, the runway can also be built as a cantilever, capable of being lowered and raised out of the way on a hinge. These four types of crane show the adaptability of double cranes.

[1] From *Engineering News-Record.*

The straight-line crane is employed for general cargo that easily passes between the legs of the gantry. It reaches well into the pier and can operate without danger of conflict with the ship's rigging. The load is moved in the shortest way possible and only needs to be lifted to the height required without having to be lifted over deck superstructures as is necessary with revolving cranes while swinging the load. The runway can be designed to reach over two ships allowing direct transfers from the ship to a lighter beyond. Such movements constitute a large part of the traffic of many ports. A revolving crane is not well adapted to this kind of transfer as the ship's masts and yards constitute a serious obstruction to radial movements of any considerable extent. The grab of the straight-line crane is usually built for a capacity of 1½ tons, which is



(From Hamburg und seine Bauten.) *(Built by Demag.)*

FIG. 71.—Double or combination wharf cranes. Straight-line and revolving jib.

sufficient for general cargo. It works with the high speed of 400 feet per minute and as no superfluous work has to be done upon the load 40 cycles per minute can be easily attained. Under the same conditions a revolving crane could accomplish only 25 cycles and would require more current for the same amount of work. The winch is of a very simple design and well adapted to the rapidity with which the load is moved. The hoisting and grab traveling ropes are taken up by two drums which can be worked separately or simultaneously.

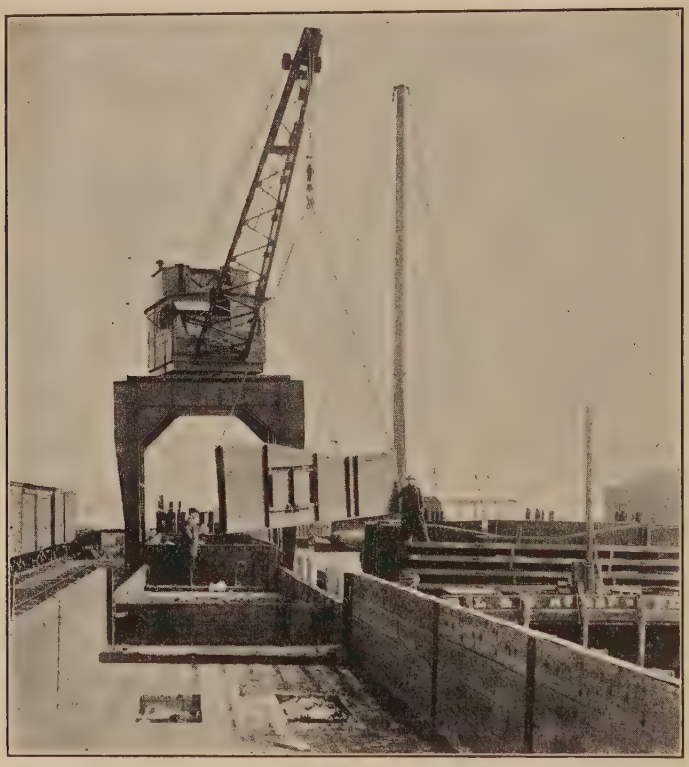
The revolving crane is usually built for a capacity of 3 tons, a larger load than ships' gear can handle. Loads of nearly double the capacity of the single draft can be handled by two cranes working together.

In order to work a hatch at full capacity two cranes can be so placed together that four hooks are available for one hatch, the two straight-line cranes working

in the center while the revolving cranes are handling freight at the corners of the hold. By spotting the booms, no time is lost in finding the opening of the hold with each successive draft. The revolving cranes can also be working the corners of the hatch while the straight-line cranes are handling deck loads.

The longitudinal travel of the whole crane is effected by means of a hand-traveling gear where the cranes are placed close together. For cranes that have to travel a considerable distance along the quay an electrically operated gear is provided.

The cranes at Hamburg were furnished by the Demag Company, Duisburg, Germany.



(*Courtesy of McMyler Interstate Company.*)

FIG. 72.—A heavy-duty (20-ton), full-arch, portal crane spanning railway tracks. Used to transfer heavy pieces of freight from flat or gondola car to lighter or ship.

Relative Merits of Dockside Cranes.—Wherever the volume of freight and available space warrant it, gantry cranes are economical and efficient transfer machinery. It is often argued that the reason why European ports use cranes is because the freight cars are open, and the Americans do not use cranes because of the prevalence of the box car. This is like saying that it is warm in summer because there is no snow. The fact that the cranes are used extensively is the reason for the prevalence of the open freight car (Fig. 72).

One reason for the use of the crane is the fact that the large proportion of water transportation by barges makes unloading machinery on shore necessary. The barges carry only a mast, which is unstepped in port, and a hand-operated hoisting drum. Another potent reason is the fact that the equipment is supplied by municipal port authorities not looking to a large return on the invested capital. Still another reason is the fact that more cargo passes over a municipal public quay per linear foot and therefore the burden of the additional cost of the quay equipment due to the cranes is more diluted per ton lifted. A final reason is that the quay has more room back from the water's edge than the pier.

Piers of the usual New York type, by their very nature, are not capable of either accommodating cranes or furnishing them with sufficient tonnage to make them economical. The difference in the tonnage transferred per linear foot of improved quay here and abroad is due partly to the nature of pier traffic, which allows a longer idleness of berthing space at piers than at public quays.

The Number of Cranes Required.—The number of cranes required depends on the amount of freight which will pass over the quay paying crane dues to support the cranes. At Hamburg, in the new basins, the cranes are spaced every 60 feet. If the city borrows money at a low rate of interest on the bonds and builds an equipment which has to support only the interest on the bonds and amortization, it can afford to be generous. Here is a great difference between the municipal and the private terminal. See Table III.

Relation of Cranes to Sheds.—To accommodate cranes it is necessary to set the transit shed back some distance from the water's edge. This immediately gives a greater area of deposit for the freight as it comes from the hold. Herein is one of the great advantages of the crane. One of the most vexing points of congestion is the point of deposit on the wharf. The area on the usual narrow pier, completely covered by shed, where the cargo from each hatch is to be set down is not over 8 by 8 feet, or 64 square feet. To work the cargo at full speed the longshoremen must remove each sling load from this point of deposit immediately, as every half minute a new sling full arrives. Above all else cargo must not "hang," waiting for space in which to be deposited. A wharf with the shed set back 30 to 40 feet and served by two jib cranes for each hatch will have a deposit space of 5,000 square feet or more. The larger area acts as a reservoir to take up the slack in the movements and avoid congestion opposite the hatch.

At Antwerp, on some of the older quays, there are no sheds at all. In the newer basins the sheds are set well back, but the floor is the same level as the quay (see Figs. 77 and 78). According to the usual practice at Christiania, Copenhagen, Hamburg, Bremen, Havre, and many other places, the floor of the transit shed is elevated to the floor level of the

FIG. 73.—Semiportal gantry crane, with car tracks set flush. Hamburg.

FIG. 74.—A modern quay equipment at Hamburg.

(*Courtesy of Ralph H. Ackerman, U. S. Commercial Attaché.*)

FIG. 75.—Valparaiso, Chili. Cranes at the quay before the custom house.

Table of Units Permitting Comparisons of Transfer Performances (General Cargo)

____ For ____ Wharf: Length ____ Breadth ____

	(1) Tons Transfer Per Hour Max:	Min	Av	(2) % of Total Working Time Berth Occupied By Vessel.	(3) No of Cranes or Other Eqpt.	(4) Tons Per Annum Per Ft. (m) Wharf	(5) Tons Per Annum on Wharf M² or Ft²	(6) Cost Per Ton Transfer	(7) Cost Per Ton other Handling Over Wharf & Shed
Offshore									
Coastwise									
Inland									
Remarks									

FIG. 76.—Chart suggesting possible units of comparison of crane performance.

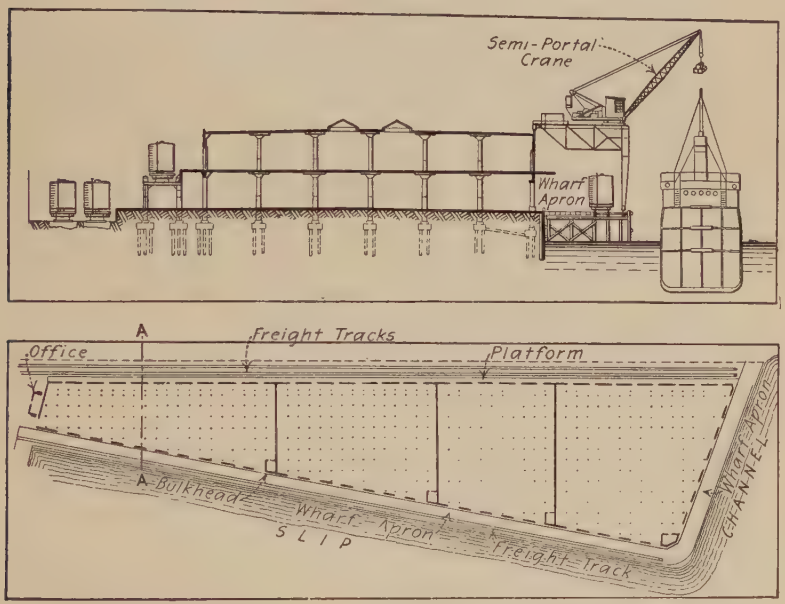
(Photograph by the author.)

FIG. 77.—Portal cranes along the quay of the Basin Bonaparte.

(Photograph by the author.)

FIG. 78.—Antwerp equipment with sheds set well back and full-arch gantry cranes.

railroad cars. In front of the shed is an open, uncovered extension of the shed floor 6 to 12 feet wide. This serves as a point of deposit from which the laborers take the freight into the shed. However, by rapid unloading this space may be filled. The cranes then deposit their loads anywhere in the intervening space.



(*Ford, Bacon and Davis.*)

FIG. 79.—Plan and cross-section of Galveston wharf and cotton warehouse with gantry crane equipment.

Shipside Moving Platform.—The problem of clearing the point of deposit on the wharf to prevent cargo from "hanging" has been solved in certain places by the installation of a moving platform conveyor of considerable width. This is built of strong slats carried by two chains running over sprockets and driven at a slow speed by an electric motor and reduction gears. A draft of discharged cargo, deposited on the conveyor, has moved away and into the shed by the time another draft is outturned from the ship. This practice, however, has many disadvantages, such as excessive wear and tear of the conveyor from hard usage, and the difficulty of making up hand-truck loads of packages going by on the moving platform.

Large Drafts on Platforms.—The more general method has been to increase the size of the draft, (Figs. 55, 56) as at Manila, by placing the draft with the sling onto a platform. This is picked up by a platform-lift, electric storage battery truck and trucked away to a place

in the shed or at the box cars. The congestion occurs when large sling loads of packages must be broken down into hand-truck loads and removed piecemeal by the wharf gang. Before they are out of the way the next draft is hanging. When the whole draft is trucked away at once one electric truck operator can replace several hand-truckers and clear the point of deposit with one motion.

Shipside Railroad Cars.—At European ports, gantry cranes, spanning the space of 30 to 40 feet from the water's edge to the shed floor, span two or three sets of railroad tracks between the shed and the water. These tracks are in addition to the tracks at the back of the shed. The position of these tracks has given rise to the supposition that cargo is usually loaded directly between car and ship. This was shown above not to be the case. Some freight, however, is loaded this way. Wherever the commodity is in large and heavy or bulky packages such as machinery, structural steel, logs, automobiles, etc., the loading does take place from car to ship. All such commodities both here and abroad are moved on flat cars or gondola cars from the point of origin to within reach of the crane for loading. It is uneconomical to have wharf cranes of greater capacity than 5 tons, and usually they are about 3 tons' capacity. Very heavy pieces are loaded and unloaded by derrick lighters.

The waterfront tracks are therefore intended for the particular heavy-duty loading as stated. When this kind of freight is not being delivered or forwarded from the water's edge the tracks are kept clear in order not to interfere with the movement of the cranes. The first and last consideration is speed in unloading the ship. After the ship has left the berth the cars may be brought alongside the water side as well as the land side of the transit shed and loaded from the shed door.

Cranes Handle Barge Cargo.—After the steamer has discharged its cargo and has gone, barges and lighters come alongside the wharf to take on their freight. These vessels were forced away from their accustomed berth opposite to the ship on the other side of the pier when we put tracks back of the shed and doubled the width of the pier. In the forwarding of freight by lighter and by barge the cranes are now able to perform a great service. After the steamer left, taking its tackle with it, there was no equipment to load onto the small craft. But with cranes on the wharf, they are kept busy in the intervals of unloading ships in handling cargo between the transit shed and the small vessels. This seems to be one of the best uses of the crane. This fact is recognized by Mr. Anderberg and the other Barge Canal Terminal Engineers in designing the canal terminals at New York and in particular the Gowanus Bay Terminal, South Brooklyn. Pier 6, East River, New York, Barge Canal Terminal has both half-portal gantry and straight-line cranes as shown in Fig. 80. These piers are designed with cranes on the barge side, while the ocean-ship side of the pier is equipped with the very efficient cargo

mast. The need of crane equipment for all new quays at NewYork and New Orleans will become increasingly urgent with the renaissance of inland navigation.

The economy of the crane is increased by the fact that it is used not only for the short time an ocean ship is discharging or loading, but also during the time in between, while serving the craft which collect or distribute the cargo of the ship. For instance, the municipal quays at Hamburg make a charge of about 3 cents a ton for the use of the cranes. When the freight is transferred from the ship onto the wharf one charge of 3 cents a ton is collected. When the crane loads part of the cargo from the wharf into lighters or barges, during the time between ships, another 3 cents per ton is collected. The cranes instead of earning their salt only

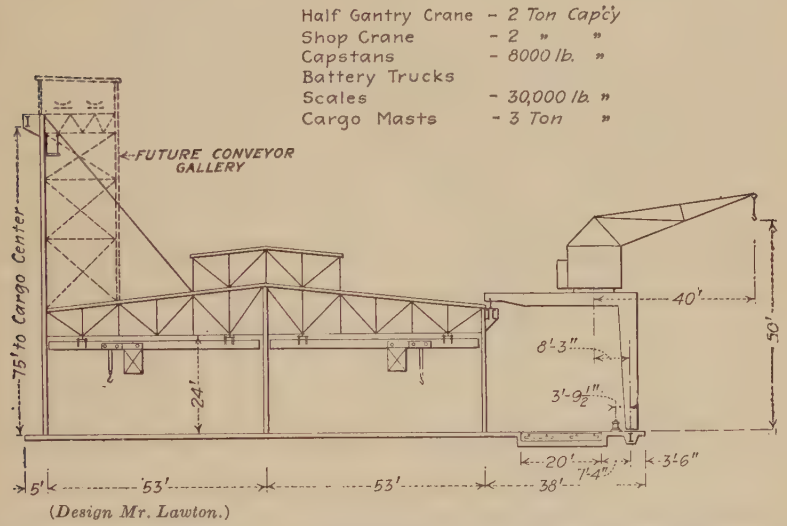


FIG. 80.—Cross-section of the Gowanus Bay, New York Barge Canal Terminal. The wharf for ocean vessels carries cargo masts and grain conveyor gallery. The canal barge side is provided with gantry cranes to serve towed vessels without power or own transfer equipment.

when working the ship are actively useful when the ship is away. This very simple fact is usually overlooked, the entire attention being directed to the more important movement of discharging the ship. The entire transfer problem of marine terminals needs much more research and analysis than the confines of these pages can suggest.

It will be observed in all of these ports that the municipal or state port commissions continue to install quay cranes to handle general cargo, increasing the density even to the point reached in Hamburg of installing a revolving jib crane above a straight-line traveling trolley crane. The entire work of transfer is given to these cranes.

The introduction of wharf cranes for general cargo at ports in the United States has been in addition to cargo mast equipment and as a supplement to it. There are several notable examples:

	Length of wharfage, feet	Duty, tons	No.	Density, feet	Year opened
Boston Quarter Master Base...	1,600	3	4	1:400	1918 to 1919
Charleston Quarter Master Base.	2,100	15 to 40	4	1:525	1918 to 1919
Staten Island, New York City (Each of two piers).....	2,260	5	17	1:133	1921
Pier 7, Manila, Philippine Islands	2,800	2 15	14 2	1:175	1925

In all of the American examples there is full reliance placed on the cargo mast with ships tackle usually used alone, while cranes are used as auxiliaries. The cargo mast is the typical American installation although the union purchase, using two ship's booms, has been in general use throughout the world for generations.

Crane densities as compiled from a questionnaire to various foreign ports, are shown in Table III.

Evaluation of the Efficiency and Economy of Transfer Equipment at Ports.—The discussions of comparative performance have been largely of a general nature because the statistics of transfer performance, even when given, are not comparable. There have been no concerted efforts made by port authorities to adopt a uniform system of statistical records to permit of comparisons among the various ports of the world that might lead to the formulation of definite conclusions as to the relative worth of the various types of machinery and methods used.

To circumscribe the subject, under *transfer*, is understood the movement of general cargo between ship and wharf. Other handling methods are not included in the discussion. By general cargo is meant merchandise in containers, thus eliminating bulk cargo. However, further subdivisions should be made of all general cargo. There are extra heavy lifts, greater than 2,000 pounds or 1 ton, that require separate treatment. Also, standardized packages and specialized freight, such as cotton in bales, wool in bales, tierces or hogsheads of leaf tobacco, and such other commodities as bananas, are frequently handled at certain ports almost to exclusion of miscellaneous freight and are capable of treatment by specially designed mechanical equipment. Note should be made of the fact if such cargo predominates.

In the scope of this discussion only hatch transfer from ocean ships, and not side port transfer will be considered. A similar set up for side port transfer is provided for in the table (Fig. 76). Coastwise and river

TABLE III.—WHARF CRANE DENSITY (GENERAL MERCHANDISE)

(From replies to a questionnaire sent to a number of typical ports in various parts of the world)

Location	Length of wharf, feet	Number of cranes 2 to 5 tons, total wharf	Average per 500-foot berth 1 to 5 tons	Annual tons per lineal foot	Annual tons per square foot wharf shed	Land or floating heavy-duty equipment	Remarks
Auckland, New Zealand, Princess Wharf.	1,230	22	9	?	?	1 at 80 tons floating	Tonnage figures not yet available.
Brussels (Belgium)	.....	28	.....	.....	.....	2 land	1 crane every 56 feet.
Bahia (Brazil)	3,281	13	.....	122	.....	4 at 4 to 150 tons floating	1 crane every 252 feet.
Casablanca, Quay des courriers.	1,312	21	8	700	20	3 at 6 tons land 1 at 25 tons land 1 at 100 tons floating	
Gothenburg (Sweden), (all five quays).	14,835	104	3 to 5	300	.....	1 at 22 tons land	1 crane every 62 feet.
Hamburg (Germany), thirty-one quays for ocean shipping.	158,144	1,123	7 to 15	90	1	1 at 80 tons floating 9 at 10 to 250 tons land 3 at 15 to 100 tons floating	Average for whole port, 1 crane every 142 feet. Cranes can be concentrated up to 3 per hatch, 15 per berth.
Liverpool (England), (total lineal quayage). Not incl. Gladstone 2¾ miles. Not incl. Birkenhead 9 miles.	(27 miles +) 142,560	.....	.....	.....	.....	28 at 7 to 87 tons land 5 at 25 to 200 tons floating	Average 1 every 60 feet. Many more light- and heavy-duty cranes at private quays and ship yards.
Gladstone Docks opened 1925	No. 1 S. 1,502 N. 1,252 No. 2 S. 1,277 N. 1,202	41 quayside 3 tons 17 roadside 1 ton 100 jiggers 15 hundredweight	4 quayside 2 roadside	.....	.....	.....	1 crane every 128 feet.
Malmö (Sweden) Old and New Harbors	20,360 (6,210 meters)	20	8	60 (1923)	.....	2 (land)	
Free Port	2,278 (695 meters)						
Oslo (Christiania)	(10,798 meters)	31	3	.....	.....	9 at 2 fixed 1 at 50 tons floating	
Rangoon (Burma). Sula Pagoda Latter Street	1,500 1,300	15 at 3 tons 16 at 35 hundredweight	6	22	0.6	2 at 7 tons 1 at 30 tons (land)	
Reval (Tallinn) (Esthonia) Rouen (France)	No. 1. 2,000 No. 2. 3,100 25,700 (7,839 meters)	4 at 1½ to 3 tons 6 at 1½ to 3 tons 156 land 125 floating	4 6 3 land 4 floating	60 400 (record 900 1918)	 13	5 at 25 to 65 tons (floating) 7floating	
Southampton, Ocean Dock (only) 1925.	3,200	16 (79 for the port)	4	60	1.72	1 floating 150 tons	

vessels, having side ports, also covered lighters with side ports, scarcely enter into consideration due to the fact that the cargo is not lifted but moved sidewise by horizontal conveyors or by hand trucks.

The center of attention is general cargo transferred through ship's hatches between wharf and shore. Therefore, the question is: *What methods are the most economical per ton of cargo transferred* with due consideration to services, claims, or dispatch, and the interests of both shipper and carrier?

Inasmuch as modern cargo vessels are now fully equipped with their own transfer machinery, the burden of proof is thrown on the shore equipment to justify the heavy investment in transfer equipment ashore. Shore equipment must earn its own overhead plus the overhead of the idle deck equipment. The wharf equipment may earn this in serving barges and in other ways. Crane equipment presupposes a sufficient continuity of the movement of freight over the wharf to make it pay to give the crane operators a fairly full number of hours of work in order to keep them on the job and to permit them to keep their hands in; to develop their dexterity in handling their machines. But it is necessary to handle a sufficient amount of pay freight per year to distribute the expense of installation and operation over a sufficient volume of business at the wharf, otherwise the charge of transfer cost against each ton of freight handled wlll be too great.

$$\frac{\text{Interest, depreciation, maintenance, and operation plus per cent of port overhead}}{\text{number of tons transferred over wharf}}$$

equals cost per ton for transfer.

Heavy lift equipment is essential at any port. It has become fairly general practice to handle heavy lifts, pieces of 5 tons and upwards, by means of floating derricks or pontoon cranes. Large packages do not recur at any one ship's berth sufficiently often to make it pay to have such a heavy duty crane stand by at all times. In a smaller port, one 75-ton floating derrick can serve the entire port. One or two such pieces of equipment may not pay for itself by direct transfers in the course of the year, but is necessary to the service of the port and a deficit in the operation of the crane itself must be charged to general expenses or advertising. Also such a heavy duty crane on the wharf will necessitate heavier construction of the full length of the wharf over which the crane may occasionally operate. Therefore, place the heavy duty crane on a pontoon and make it more mobile in addition.

At present, there are no means nor methods at hand to make possible such a comparison as to relative efficiency. By means of a short questionnaire to the leading ports in the world, the writer recently made an attempt to establish some sort of basis for comparison. But little was gleaned due to the lack of uniformity in statistical methods. It is

necessary to arrive at some basis of comparison and the following analysis and suggestion are therefore presented for consideration in the hope that some method may be developed. The following variables in the equation may be listed. It is desirable to ascertain the crane density, that is, the number of cranes per lineal foot of wharf. To the cost of the cranes must also be added the additional cost of the structure to carry the crane equipment. For the sake of standardization a berth may be taken as 500 feet, an arbitrary length. To the annual cost of operation, interest, depreciation, etc., of the cranes must be added the interest and amortization of the structure. These can then be reduced to a basis of cost per ton per lineal foot of wharf and charged against the ton movement. This method will therefore give us a comparative figure of the unit of *cost* of transfer.

But, as cost is not the entire factor, we must arrive at a unit of comparison that includes dispatch. The port renders a service when it enables a ship to turn around quickly. It is necessary to know the rate of discharge and loading of the ship in tons per hour as the working day varies as to the number of hours in the different ports of the world. A rate of discharge of a ship may be taken as "X" tons per hour. This will give a unit of measure of service in addition to cost.

Also, the performances of terminals are on trial. There are two methods of comparison of terminal performance suggested. One unit of comparison will be obtained by reducing the annual tons of cargo transferred over the wharf to the basis of tons per lineal foot or per lineal meter. The other basis of comparison by which to judge the efficiency of the wharf is the total annual general cargo tonnage handled over the wharf expressed in the unit of square meter or square foot of wharf area. This wharf area taken for comparison should include the string piece and the transit shed back to the inshore wall. If there are rails or roadway on the inshore side, the car- or dray-loading platform is not an item or calculation of *ship* performance and should be omitted from the calculation.

The difficulty of arriving at these statistics is obvious. It is grossly inaccurate to divide the total tonnage movement of a port by the total improved frontage. Calculations must be made for each unit of wharf handling miscellaneous general cargo with such subdivisions as necessary to include specialized freight as mentioned above. Otherwise, the total freight tonnage movement of the port would include bulk cargo of various types, bunkers, and other tonnages not under consideration.

Given the tonnage figures per lineal foot or per square foot of wharf, it is possible to arrive at handling costs and dispatch reduced to a comparable unit. In addition to the physical transfer with or without cranes and equipment over the lineal frontage of the wharf and the handling efficiency based upon tons per square meter or foot, there should be

added to the overhead consisting of interest and amortization and insurance on the plant a certain percentage of total port overhead, that is, proportion of cost of administration. In setting up the tables of performance statistics of any port, the methods of calculation at that port should be given. It should be stated what the insurance rate, the interest rate, etc., is—also the nature of traffic, seasonal or distributed throughout the year, low, high, or average by days or weeks or months. As these conditions would differ widely in various ports of the world, the investigator who was endeavoring to make the comparison should have these facts well in hand as well as the other units of comparison as a basis.

May it be suggested that a statistical method be adopted to include the following factors: 1. Tons per hour discharged and loaded, maximum, minimum, and average. 2. Percentage of total time berth is occupied by ships. 3. Crane density, number of cranes per lineal foot or meter of wharf. 4. Total transfer per year per lineal foot or meter, maximum, minimum, and average. 5. Total cargo handled over the wharf per year per square foot or square meter. 6. Cost per ton of transfer. 7. Cost per ton of handling over wharf and through transit shed. 8. Distribution of time in use and tonnage handled between offshore, coastwise and inland water vessels for all the above categories.

Given these units of comparison reduced to a common denominator with explanatory footnotes concerning the nature of the figures used at each wharf, there will then be material in hand to judge the relative cost of efficiency of the various transfer methods as between sections of the port and between widely distributed ports of the world. Upon these one may base an opinion, with some degree of accuracy, of comparative transfer and handling efficiency.

CHAPTER VI

TRANSFER AND HANDLING OF UNIFORM SIZES OF PACKAGES OR SPECIAL FREIGHT

Terminals which handle a large tonnage of freight of the same kind lend themselves readily to labor-saving machinery. There are two classes of specialized freight, package and bulk. Illustrations of uniform package freight are coffee, sugar, seed, rice, etc., in bags, paper in rolls, crates of fruit, bananas in bunches, cottonseed cake, leaf tobacco in 1,000-pound, hogsheads, or tierces, and many other commodities of similar character in containers of uniform size. Bulk materials are coal, ore, petroleum, grain, in fact any materials in liquid form or in comparatively small pieces not packed in containers. The two groups present two different mechanical problems.

The general principles of port layout are as effective in the case of either group as in the case of miscellaneous package freight. There is transference between ship and land, there is the transit storage shed to hold the cargo awaiting the ship or to take the cargo as quickly as discharged, and there is the larger reservoir, the warehouse. The warehouse for specialized freight may vary from the usual type used for general package freight to great tanks of bulk oil, grain elevators, or the stock pile of coal or ore. These "warehouses" are constructed to accommodate a particular commodity. The stock pile for ore or coal is a warehouse.

Bulk and specialized freight offer an opportunity for the continuous-motion principle, while in general cargo package freight there is little hope of getting away from intermittent motion. Any commodity which may be pumped, such as liquids or grain, or moved by belt conveyors, as coal, or by package conveyors, as bananas, boxes of apples, and bags of coffee, affords an opportunity for economy through mechanical ingenuity.

For the sake of clarity it may be pointed out here what is meant by various terms that are given to operations generally included under the expression "cargo handling at ports." Under this general term of "handling" there are several definite subdivisions:

Place	Activity	Labor
I. Aboard ship	1. *Stowing*	Hold gang
	2. *Breaking out*	
II. On ship's deck and wharf apron	*Transfer*	Deck gang
		Winch runners
		Crane men
III. On wharf and in transit shed and warehouse	*Handling*	Longshoremen
	1. Trucking	Shore gang
	2. Tiering	Shore labor
		Wharf labor
		Truckers
IV. On wharf and in transit shed and warehouse	1. *Weighing*	Special contractors
	2. *Sampling*	Longshoremen
		Shore gang
		Shore labor
		Wharf labor
		Truckers
V. At railroad tracks	1. Loading cars	Longshoremen
	2. Unloading cars	Shore gang
		Shore labor
		Wharf labor
		Truckers

Transfer Movement.—Little progress has been made in the development of continuous movement of bags or bales from ship to shore. The reason may be that the crane has been developed to such efficiency that it has not been necessary or very profitable to design continuous-movement unloading machinery. Bags and crates unloaded through hatches are lifted in the rope or platform sling by boom or crane and deposited on the wharf deck for handling. In some cases, notably at Santos for coffee loading, the conveyor has a movable section permitting it to be extended to the deck of the ship where the bags of coffee are fed to the slings which lower a sling full at a time into the hold. At Santos the horizontal travel from warehouses to shed and to ship is done by means of belt conveyors which are built along the outside of the building.

Banana Unloaders.—The method of handling in slings did not work well for bananas as the fruit was bruised. As the banana trade increased in importance throughout the world the terminals of banana steamers at Hamburg, New Orleans, and elsewhere, were fitted with a specially devised banana unloader. The most successful type and the one with the greatest capacity has been installed by the port of New Orleans, the port of Galveston, and elsewhere.

Banana importations at New Orleans exceed those at any other port.

The banana imports have been as follows:

Year Ending	United States	New Orleans
June 30, 1911	44,699,222	13,611,860
June 30, 1918	34,549,913	18,908,440
Dec. 31, 1920	39,319,562	20,071,441
Dec. 31, 1921	43,365,763	19,811,883
Dec. 31, 1923	.....	18,749,600

New Orleans is now importing more than half the bananas brought into this country.

The port has three fruit landings, designed to expedite the handling of green fruit. Special railroad facilities and banana unloaders make possible the unloading of 10,000 bunches of bananas from a ship in an hour.

The average ship carries about 40,000 bunches, taking from 4 to 5 hours to unload.

The handling of this business by mechanical devices has been developed until practically all of the bananas are now unloaded by machines. In 1923 there were 13 such unloaders.

The design of this machine is complicated by the necessity of providing for a wide range of water level and ships of various dimensions. The machine consists of a steel "A"-frame structure traveling lengthwise of the wharf on two rails about 21-foot centers, and carrying a structural steel main boom 50 feet in length, stepped about 20 feet above the deck level.[1]

On this boom, at a distance of about 30 feet from the heel, is stepped an auxiliary boom 20 or more feet in length, from the end of which is swung the vertical leg of the conveyor. These two booms afford almost any desired combination of vertical and horizontal adjustment, while at the same time the main boom is sufficiently short to clear the stays and wireless rigging of the ships.

These booms and the framework carry the conveyor proper, consisting of two endless chains spaced about 5 feet apart and running over pairs of sprockets at the foot and head of the conveyor frame, at the pivot points of the auxiliary and main booms, and at additional points at the discharge end of the unloader, as shown in sketch (Fig. 81).

The distance between chains is maintained by pipe spreaders and through bolts spaced about 3-feet centers, attached to which is a 4-foot canvas belt with sufficient slack between each pair of spreaders to hold a bunch of bananas when the chain is moving vertically.

Upon reaching the point of discharge the bunch is forced out of the pocket by a roller behind the belt and drops upon a short horizontal conveyor from which the bunches are picked up by hand, inspected, sorted, and loaded into cars, or disposed of locally.

[1] The equipment is described in a booklet issued by Ford, Bacon and Davis, the engineers designing the municipal wharves, warehouses, and elevators at New Orleans, Louisiana.

The entire machine is driven through gearing and clutches by one 15-horsepower motor. The capacity of each machine is upward of 2,600 bunches per hour.

Three groups of these unloaders, consisting of ten units, are owned by the Dock Board, the total investment being about $90,000. The most recent installation is at the Pauline Street wharf and consists of four machines costing approximately $37,500. The section of the wharf on which they operate is of pile and timber construction with steel shed, about 360 by 260 feet. As the area is covered rain does not interrupt the discharging of cargo. The wharf is served

(Courtesy of Board of Commissioners of the port of New Orleans.)

FIG. 81.—New Lamson Conveying System. Banana unloader installed for the Cuyamel Fruit Company at the Desire Street Wharf, New Orleans.

by eight transverse spur tracks accommodating five cars each, and as one ship may carry 40,000 to 45,000 bunches or about 120 carloads, the entire track capacity may be filled and moved three times in less than a day's time. The cost to the Dock Board of this wharf with its shed and tracks was about $1.40 per square foot. In the rear of the wharf the Public Railroad has yard capacity for 200 additional cars.

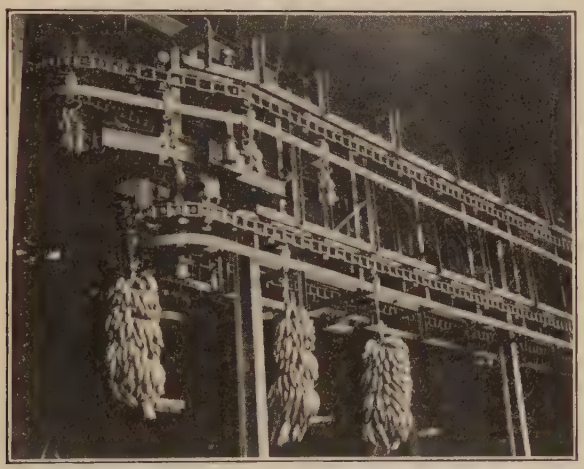
The Board of Commissioners makes a charge for the use of the banana conveyors of ¼ cent per bunch, which considerably exceeds the cost of operation, maintenance, and interest charges.

The Lamsen Banana Unloader and Conveyor (*New Orleans,* 1922) (Figs. 81–82).[1]—This equipment has incorporated in it many new ideas in

[1] Data furnished by H. M. Gallagher.

the handling of merchandise in uniform or nearly uniform packages. This particular installation was made primarily for the handling of bananas, the idea being to transport the bananas from the hold of the ship to the doors of waiting refrigerator cars for immediate shipments to points north, east, and west of New Orleans. The idea was so to construct the apparatus as to make it possible to handle sacked goods of various kinds.

In the new system instead of carrying the bananas in canvas pockets on the outer and upper side of the conveyor, the bananas were carried on hooks on the inner and lower side of the conveyor. The hooks are fastened to crossbars spaced on about 5-foot centers. A cord forming a loop is attached to each bunch of bananas at the port of shipment. This loop is dropped over a hook of a small, single-wheel trolley of novel design.



(Courtesy of the Board of Commissioners of the port of New Orleans.)

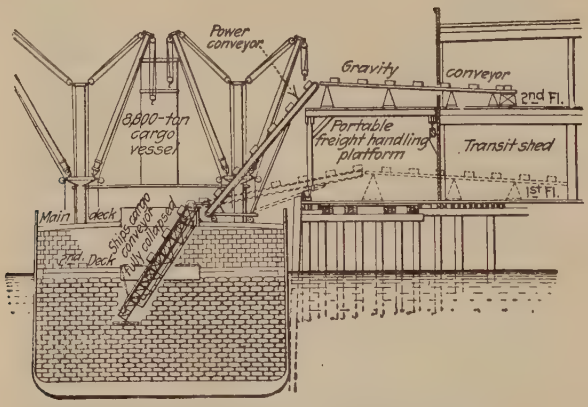
FIG. 82.—Lamson Chain Trolley Conveyor. Note return of hooks. The system requires the attaching of cord loops to the stems at point of shipment.

The Lamsen system of conveyor has been working very well in all cases where it has been possible to insure the attachment of the cord loop to the stem of the bunch of bananas at the point of shipment, as in Central America and elsewhere. When this has not been done the delay and cost of affixing the loops at port of destination (New Orleans) has overtopped the advantages. It is a close question for decision whether the advantages of the conveyor outweigh the increased cost of the installation and the labor of the loops compared with the horizontal belt conveyors now in use.

In this connection it is instructive to observe that, in the beginning, first the unloader itself, then the inspection of the bunches while moving on a belt conveyor were derided by contracting stevedores as visionary and impractical. As in other forms of progress, such as the power-loom

and the linotype, working men thought they saw decreased employment. The reverse is usually the case because better methods and lower costs mean increased demand and increased business at higher wages. All progress must overcome inertia and even direct opposition.

The ship cargo telescope conveyor (Fig. 83) is described by G. F. Nicholson, Chief Engineer, Los Angeles Port Commission, for which he claims twice the speed of discharging compared with the old methods. This conveyor is similar to all portable and horizontal continuous-motion belts. The difficulty in operating such conveyors in holds of ships has been the fact that the angle of rise is so nearly perpendicular that the packages roll off the conveyor. This is overcome by various methods of slats or slack pockets. The conveyor is lowered bodily into the hold, hooked onto the hatch combing for support. The length extended is 45 feet, and the



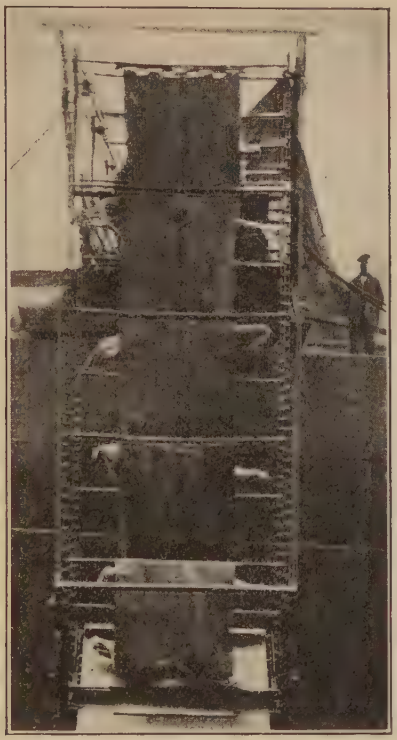
(*From Engineering News-Record, January* 26, 1922.)

FIG. 83.—Portable telescope conveyor for the transfer of ships cargoes as installed at the port of Seattle. Conveyor fully collapsed in hold of vessel.

length collapsed is 29 feet. Its width overall is 5 feet 6 inches, and the depth overall is 4 feet 6 inches. It weighs 3½ tons, and can be handled by the ship's boom. It is run by a 10-horsepower motor, has a capacity of 125 tons an hour, and a speed of 75 feet a minute.

With the present method of discharging canned salmon by slings, the capacity will average 800 to 1,000 cases an hour. The conveyor will handle 2,000 cases an hour. It can handle boxes, bales, and sack goods up to a maximum weight of 500 pounds and maximum size 2½ by 2½ by 5 feet. It is designed to handle canned goods, sack goods, including sugar, beans, rice, bales of cotton, hemp, and silk. Other packages that cannot be taken by the conveyor are transferred from the other end of the hatch with the usual cranes or ship's tackle. The cost of the conveyor is unusually low, $2,400 a machine.

Conveyors for Frozen Meat (Figs. 84 and 85).—In London large quantities of frozen mutton and chilled beef are transferred from refrigera-



(Courtesy of Rownson, Drew & Clydesdale.)

FIG. 84.—Belt conveyor for general cargo of limited package sizes.

FIG. 85.—Overhead monorail and trolley-hook conveyors moving frozen beef from ship to cars, London.

tor ships arriving from far-off sources of production, such as Australia, Argentina, and Uruguay, to feed the dense population of Great Britain. The handling of refrigerated products, particularly meats, involves special equipment, suited not only to the size of package, but the entire installation must be arranged to permit inspection and at the same time prevent undue change of temperature. Mutton is handled essentially the same as bananas at New Orleans. Beef is transferred from the ship in web slings and on the wharf, is conveyed either by belts, as in the older system at New Orleans, or on a trolley chain and traveling hook almost identical with the Lamsen system for bananas.

A continuous motion unloader on the slack apron has been put on the market in principle similar to the original form of banana unloader, but much more difficult of adjustment. The outboard section of this machine, as well as the leg extending into the hold, is shown in the accompanying photographs (Figs. 84 and 85). The principle involved is understood at a glance. Where a large quantity of one type of cargo is to be discharged or unloaded, this form of conveyor offers great savings, but the time and expense involved in setting the mechanism, necessitating cranes to lift it and set it in position, have been a deterring influence in the wide adoption of the system.

In the first edition of "Ports and Terminal Facilities," (p. 199), there is the statement that in the banana unloader we may observe the elements of the future continuous motion transfer equipment for all containers of comparatively small dimensions and weights. Much progress has been made toward that end during the intervening 7 years and therefore the following observations are not amiss:

The two cardinal advantages of continuous motion applied to the transfer movement are (1) speed of operation; and (2) the lifting, transferring, and lowering of each unit individually without injury due to pressures in the sling or banging the draft against ship, shed, or wharf deck. This type of cargo-handling machinery if developed should have two outstanding characteristics: (1) a self-contained mechanism, traveling along a wharf apron on a gantry, or mounted directly on crane tracks; and (2) capable of adjusting its marine leg to the various depths of hold and changing water level without delay or undue manual labor. With mobility combined with range of possible adjustment, the ultimate ambition of a continuous motion transfer will have been achieved in so far as uniform package freight is concerned. Even at the expense of frequent renewals of the belt material, the savings will undoubtedly be large compared with the method of hoisting slings.

Spiral Chute.—A spiral chute for gravity handling of comparatively small packages has come to be part of the equipment of most factories, warehouses, and piers. An application of the principle of the spiral conveyor and gravity chute to loading ships has been patented by A.

Miller McDougal, of Duluth.[1] This device (Fig. 86) consists of a boom hinged to the front of a warehouse and capable of being elevated and lowered. This boom carries a vertical leg on which the spiral chute is mounted. A roller gravity chute or conveyor from the second story of a warehouse leads to the spiral. The spiral may be revolved in order to deliver the packages toward the wings of the hatch being stowed. This machine is sufficiently illustrated in the sketch filed with the patent. The

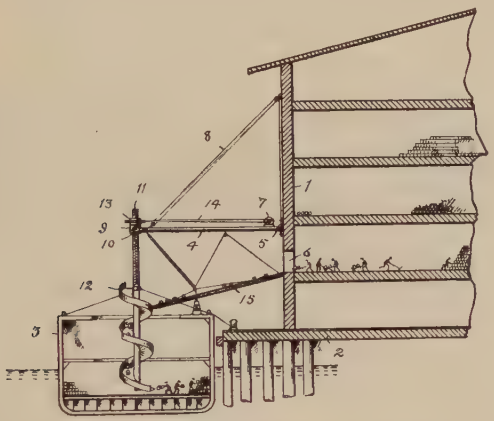


FIG. 86.—The A. Miller McDougal patented gravity spiral ship-loading device for uniform packages of comparatively small volume and weight. A bale of cotton might be considered a maximum package.

same mechanism, as shown in the drawing mounted on the face wall of a waterside warehouse, could be mounted on a cargo mast of a two-story pier shed. The writer has no records at hand concerning the operation of this vessel-loading device in actual practice. It is capable of application to barge and lighter loading, in particular from many-storied waterside warehouses of the Hamburg Free Port type.

Devices for Handling Cotton.—The chain-conveyor system of Colonel Fordyce, Texas City, for handling cotton, described in a subsequent chapter in connection with the utilization of the upland in port development, is similar to the banana, frozen mutton, and chilled beef unloaders of New Orleans and London. This cotton conveyor at Texas City has a capacity of 14,000 bales of cotton in 24 hours. This is enough cotton to load five ships simultaneously. The structure cost approximately $40,000.

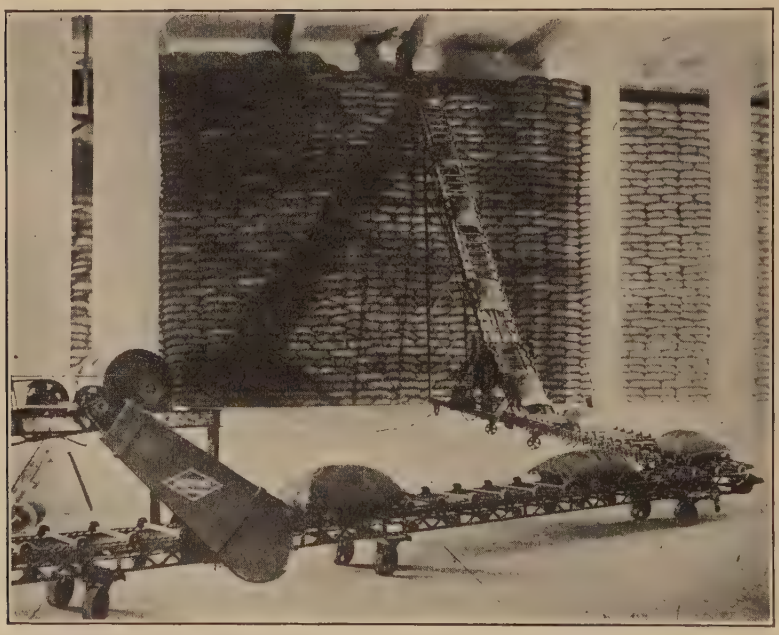
HORIZONTAL CONVEYORS AND TIERING

After the freight has reached the deck of the wharf it can be handled by efficient machines which have been devised to take care of its further movement. It has been pointed out that the chief expense at the ter-

[1] Patented Jan. 18, 1921. U. S. No. 1365929.

minal is in what we call "handling," that is, moving across the pier, tiering, breaking down the tier, loading into drays or railway cars, and moving to the warehouse. In the case of miscellaneous freight with the wide variations in the size, weight, and shape of the parcels, there has been little relief by mechanical means and the hand truck reigns supreme. When it comes to specialized freight, however, there are already many tried and proved devices, products of several firms and nationalities.

The first movement is horizontal, across the deck. The belt conveyor, either portable or stationary, is well known. Other methods were discussed above. In the horizontal movement, the saving over

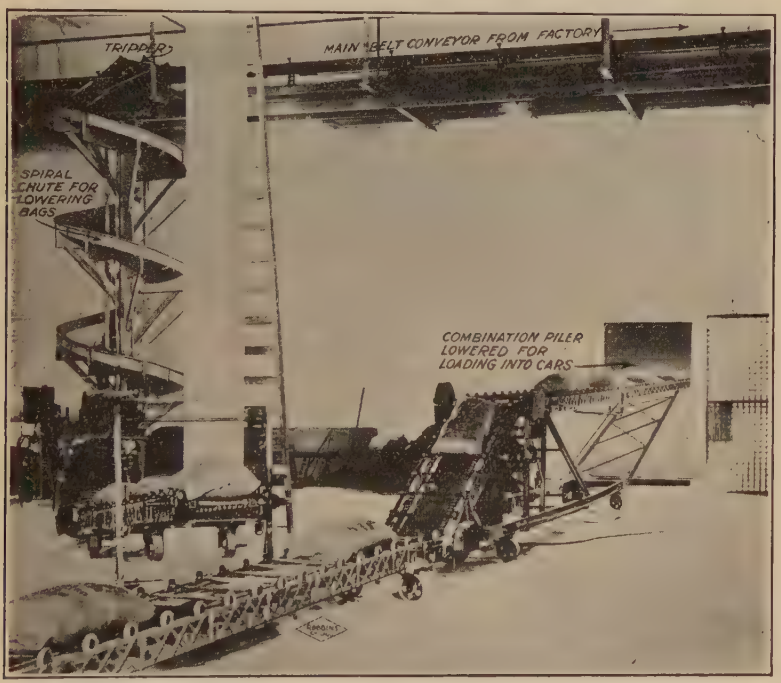


(Courtesy of Robbins Electric Co.)

FIG. 87.—High tiering in warehouse or transit shed by mechanical means.

man and hand truck accomplished by machinery is not so great as in the second movement, which is tiering. But tiering is pure muscle, undiluted brute force. Even the hand truck by comparison is a labor-saving machine not to be despised. It must be borne in mind that tiering is necessary if, for instance, the cargo of coffee for a ship is to be held ready in a shed of reasonable dimensions. To tier to the height required to husband space requires a large force of men. The tiering is done on the pyramid plan with the ledges or steps about a yard high. Each ledge requires a workman to hand the bag of coffee to the next higher ledge. Therefore every additional yard in the height of the tier means an additional man and as many handlings as the stack is high. The tiering

elevator is the solution. They have been successful wherever built by reliable firms. One case in point is the great sugar-beet seed farm at Klein Wanzleben near Magdeburg, where the beet seed in bags ready for shipment is held in large warehouse sheds with rail sidings. There are often as many as 300,000 bags of seed tiered to a height of from 40 to 50 feet by portable electric elevators. When the railroad box cars are to be loaded, the tiering machine and portable conveyor running in the reverse direction help to break down the tiers and move the bags into the box car. Our American machines are at least as efficient.


TRIPPER
MAIN BELT CONVEYOR FROM FACTORY
SPIRAL CHUTE FOR LOWERING BAGS
COMBINATION PILER LOWERED FOR LOADING INTO CARS

(Courtesy of Robbins Electric Co.)

FIG. 88.—Spiral chute and portable electric conveyors loading box car.

Tiering or stacking elevators should embody several features. Such a machine should deliver the packages at a rate which will keep the men at each end moving at an efficient speed. As one illustration, a stacker for oil cake delivers three cakes at a time every 6 seconds. Another delivers a 160-pound bag every 8 seconds. These are rather slow machines. A speed of 2 seconds would require a rather large force of men at the delivery end to dispose of bags arriving at the rate of thirty per minute. The problem, as is the case almost every time, is to design the machine for its special duty. The elevator should be in several joints to afford greater flexibility in storage and in operation. The motors and moving

parts should be well protected and simple in construction. The units should be as light as is consistent with stability, to make shifting about the shed as easy as possible. In this connection the diameter of the wheels should be as great as the design of the elevator will permit, to overcome tractive resistance in shifting the machine. There should be some means of locking the castors or wheels when the machine is in operation.

The operation of portable conveyors may be clearly seen from the illustrations. A saving of as much as 80 per cent in some cases is credited to these machines.

Telpher.—Another method of lateral and vertical movement is the telpher. At New Orleans the Chalmette Sugar Refining Company has used the telpher with success. This transfers from ship to shore, then to shed or warehouse, and also does tiering. We have familiarized ourselves with the telpher and found that for miscellaneous package freight it was not sufficiently flexible in most cases, and its use had been a failure in such instances. However, in the case of specialized freight, the telpher has been a success. As usual, from the standpoint of operating economy, the volume of materials moved must be great in order to "dilute" sufficiently the fixed charge of the expensive installation.

Telpher System, Chalmette Sugar Refinery.—New Orleans receives large quantities of raw sugar from Cuba, Porto Rico, and local production districts. The American Sugar Refining Company alone receives over 300,000 tons per annum at its large Chalmette refinery, just below the city.

This plant has a well-equipped telpher system for receiving, storing, and delivering raw sugar. This system operates between a wharf about 80 by 800 feet parallel with the river, and a storeroom about 250 feet in the clear from the wharf.

The wharf is a pile and timber structure with columns set on piles and double hardwood floor laid on a packed sand bed. This tight floor is to facilitate the salvage of raw sugar from broken bags. The column spacing on the wharf is approximately 20 feet both ways, while in the storeroom the spacing is about 20 by 25 feet. Both structures are enclosed with galvanized iron and the two are connected by four elevated runways, for the telpher system, which are also entirely enclosed.

The track system for the telphers is divided into two sections, each consisting of a loop on the wharf and four loops in the storeroom. The telphers can be operated selectively over any of the loops of a section by means of a transfer or switch which connects the tracks, as desired. The two-track sections can be interconnected by a special transfer or switch cutting off a large part of the run when ships are unloading at suitable points.

The telpher equipment consists of twenty-five machines; each has a capacity of seven bags of sugar weighing about 330 pounds each, or about

FIG. 89.

(*Photographs by the author.*)

FIG. 90.

FIGS. 89 and 90.—Inside (Fig. 89) and outside (Fig. 90) monorail arrangement for Telpher equipment at the new municipal terminals at Tacoma, Washington. The Port manager and commission expressed satisfaction with the equipment (see also Fig. 108).

1 long ton, and is equipped with two travel motors of 6 horsepower each, on a swivel truck, and one hoist motor of 5 horsepower. The telphers travel 700 feet per minute, which enables them to pick up their load, make a round trip to the storeroom, discharge therein, and be on the wharf ready for another trip within 5 minutes.

The storeroom has a maximum capacity for storing sugar of about 370,000 bags or 52,500 tons, each panel between four columns containing approximately 2,500 bags when tiered twenty-eight bags high.

Sugar arriving by water, steamship, or barge is practically all in bags. The bags are unloaded from barges or boats by three small electric derricks on the outer face of the wharf, and from ships by the ships' tackle, in both cases being deposited on the uncovered portion of the wharf. The bags are then placed on trucks in lots of two or three and trucked to a portion of the wharf which is in reach of the telphers; in the case of imported sugar, they pass over the government scales on the way. On this floor the bags are sampled and weighed for settlement with the seller, again made up in slings, and transported by the telpher to the storeroom and there tiered as already described. When sugar is to be used, the same telphers remove the bags from the tiers and deposit them at the shore end of the storeroom where they are sampled and weighed for controlling the manufacturing process. At this point the sugar is removed from the bags and is carried by bucket elevators to the refinery.

The estimated capacity of this telpherage system, as outlined, is 3,000 tons per working day of 10 hours, or 75 tons per hour per machine.

Telphers for Cotton Bales at Municipal Warehouse.—The transfer of cotton bales from the warehouse to shed and to ship is done by a telpher system in the new Municipal Warehouses at New Orleans. Few commodities require such a large reservoir as cotton, because the cotton crop comes on the market with a rush to be drawn off throughout the rest of the year. Ships cannot take it away as fast as it is produced. The reservoirs should hold a large part of the crop to guard against the calamity of a sudden shipping disturbance. Moreover, the cotton warehouse is a specialized warehouse designed to meet the peculiarities of the cotton trade.

Standard package freight handling, therefore, is being successfully solved by mechanism *versus* muscle. In the case of bulk freight the greatest progress has been made, and the United States excels all other countries.

From the engineering standpoint, such equipment is not excessively more difficult nor costly than the design and construction of gantry cranes that are now in general use about the world.

Most Merchandise is in Uniform Containers.—The following table shows alphabetically the different kinds of containers, and the number of

different kinds of commodities usually packed in each kind of container. Some of these may be further consolidated for purposes of the design of transfer equipment of the conveyor types. In other words, there are, after all, so many similar packages in commerce that the use of specialized equipment should become more common in the transfer of general cargo. Both types of transfer machinery, side by side, would divide the work according to size of package and nature of container. This is an end to be worked for. All of these items are not adaptable to continuous motion equipment, selections may be made from them to indicate the very large number of containers that are capable of such transfer and handling.

Bags	371	Casks	115	Pipes	2
Bales	445	Chests	8	Puncheons	2
Barrels	438	Coils	8	Reels	22
Bars	8	Crates	160	Rolls	48
Baskets	170	Cylinders	19	Sacks	60
Boxes	395	Demijohns	3	Scroom	3
Bulk	50	Drums	80	Slabs	4
Bunch	8	Firkins	2	Spools	4
Bundles	160	Hampers	6	Straps	4
Butts	4	Hogsheads	38	Tierces	38
Cakes	29	Kegs	166	Tubs	8
Cans	6	Packages	91	Trunks	2
Carboys	10	Pails	4		
Cases	1,749	Pieces	31	Total	4,771[1]

[1] MacElwee and Taylor, "Wharf Management, Stevedoring and Storage," p. 145; also from "Stowage Factors for Ships Cargoes," United States Shipping Board, 1919. Division of Planning and Statistics.

CHAPTER VII

THE TRANSIT SHED

The transit shed is the first and most important item of wharf equipment. At New York and elsewere the shed is limited in dimensions by the size of the pier. There is little choice in the size and proportions of the pier transit shed. The result has been that the pier and the pier shed have been considered as one and the same institution. This is not the case in theory, and in other ports with greater freedom of action is not the case even in practice. The transit shed is a thing apart.

The function of the transit shed must be kept clearly in mind. The transit shed is a covered structure to give protection from weather and pilfering to a cargo in transit between ship and land. When a ship makes port, it must discharge its cargo as rapidly as possible and cannot wait with this unloading to allow the cargo to be taken away. The cargo must also be spread out to afford opportunity to sort it according to marks and consignees. During this time, from the discharge from the ship until the goods are sorted and moved away, they must be protected. Likewise in loading, when a ship arrives and has its cargo all out it must load the outgoing cargo as rapidly as possible. This is only possible if the cargo has been assembled beforehand and sorted according to ports of destination and nature of the goods. The stevedore can work rapidly and load correctly only when the cargo can be loaded and stowed in the proper sequence. Stowing according to port of destination is very important when the ship is to call at several ports, as for instance on a voyage to South America.

Size of the Transit Shed.—It follows from the foregoing that a transit shed must be sufficiently large in area to hold the cargo of the largest ship using the landing, and in addition to hold it spread out for sorting with aisles between the piles of cargo at frequent intervals. The cargo must have space enough without the need of piling it more than shoulder high as this piling or tiering is very expensive and time consuming. Goods may be tiered in a warehouse but it should not be necessary to tier them for the 2 or 3 days that they are in the transit shed. The transit shed must have an unbroken floor space sufficient in area to perform this service of smooth stevedoring without congestion.

What is a sufficient area? One way to get at the answer is to consider the latest practice at some of the best ports abroad, where there has been sufficient room to build sheds the size wanted without being limited by

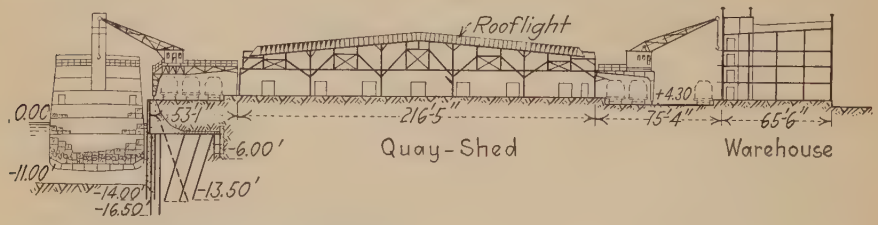
the size of the pier. As first example may be noted one of the quays[1] in Hamburg with three sheds of a combined length of 965 meters and width of 42 meters, or 40,523 square meters. This would mean a length of sheds of about 3,210 feet (1,070 feet to each shed) and a width of 140 feet, of nearly 450,000 square feet of space. The quay wall is 1,090 meters or 3,610 feet long, 400 feet longer than the combined length of the sheds. This would give an area of 150,000 square feet for each shed. Assuming an average required capacity for 15,000 tons of cargo to each shed the allowance made is 10 square feet per cargo ton. The area may have been calculated at 1 square meter (1.196 square yards) per cargo ton for a somewhat smaller average cargo. 15,000 tons and 1,070 feet of shed would mean two steamers of 475 feet of 7,500 tons deadweight or cargo measurement—about normal cargo line capacity. Ten square feet would accommodate 1 cargo ton piled 4 feet high. At this calculation it would be necessary to tier above 4 feet to make the aisles, otherwise the 15,000-ton measurement of cargo would completely cover the shed floor at an average height of 4 feet. At Bremen, the tendency has been to shorten the sheds and increase the depth. The first sheds to be built in the "free zone" were 40 meters deep while the later sheds are 66 meters deep. The latest Bremen sheds are 216 by 640 feet, which gives an area of about 140,000 square feet. This is a smaller capacity than that of the Hamburg sheds, yet, still assuming 10 square feet per ton of cargo, the shed would accommodate 14,000 tons. As this is about the limit of cargo capacity of ships coming to the port of Bremen (the very large steamers all dock at Bremerhaven) the accommodation for cargo calculated on the above basis is sufficient. The newest sheds at New Orleans—(1925) on the industrial canal—are 200 feet deep, for the same reasoning.

An important feature of the increase in the size of the sheds is that the only way to keep pace with the size of the ships is to increase the depth of the sheds. Granted that sheds should be as long, or nearly as long, as the longest ship using the berth, a simple increase in the length of the shed will not afford sufficient space on the shed floor to accommodate the increase in the size of the cargo. When a ship's size is increased it is in linear measure, but the cargo capacity at the same time is increasing in cubic measure while the shed floor is only increasing in square measure. A ship 500 feet long is 25 per cent longer than a ship 400 feet long, but the increase in cargo capacity will be considerably more than 25 per cent. To accommodate the increase in the capacity of ships it is necessary to increase the length of sheds, but the depth must be increased even more. This fact accounts for the pier congestion at New York, where it has been possible to increase only the length and not the depth, *i.e.*, width, of the pier and its shed. Bremen sheds have been made wider with each new construction, reaching 216 feet depth (Fig. 91).

[1] Augusta Victoria Quay, opened 1903. Kuhwärder Extension.

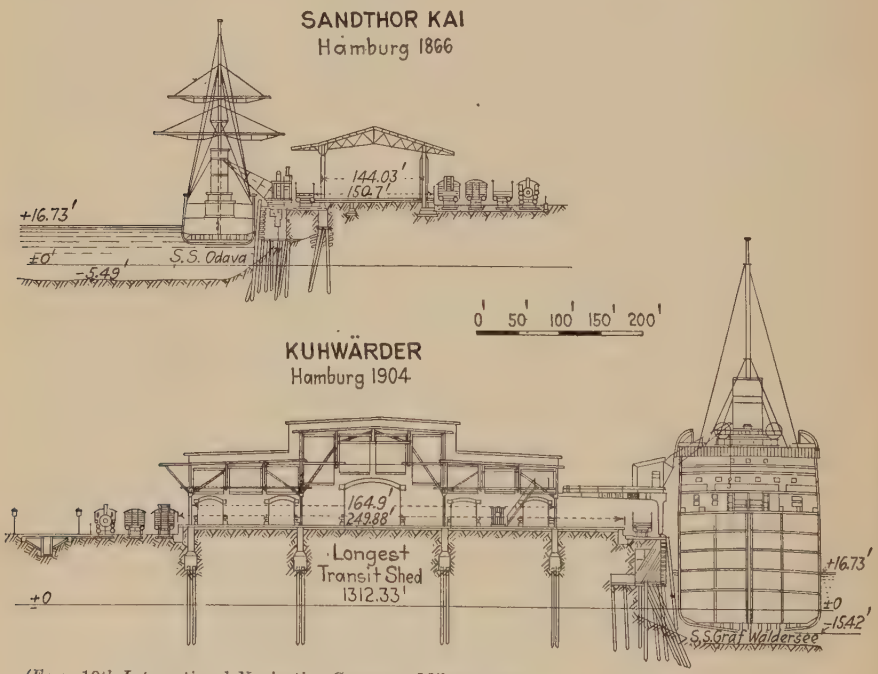
The growth of the width of the Hamburg sheds between 1866 and 1904 is shown in Fig. 92.

Recent New York practice, as found at the Chelsea piers, is to make the shed a little less than 120 feet wide and about 900 feet long (the



(*From Dock and Harbour Authority, London.*)

Fig. 91.—The Bremen transit shed with a depth of 216 miles 5 inches is wide enough to accommodate transit storage in the landward portion pending forwarding to rail dray or warehouse.



(*From 10th International Navigation Congress, Milan,* 1905.)

Fig. 92.—Typical increase in the size of transit sheds as illustrated by port of Hamburg. Sandthor Quay opened 1866, transit sheds open sides. 13.90 meters inside measure, 15.94 meters platform edge to water edge, length 80 meters.

Kuhwärder quays, opened 1904, transit sheds closed and locked. 50 meters inside measure, 61.60 meters platform edge to water edge, length 400 meters.

pier deck is 1,000 feet in length), or an area of about 100,000 square feet. This would afford a capacity of 10,000 tons of cargo. However, the Chelsea piers are of two stories and the Hamburg sheds of one. At

Hamburg it is the custom to move the ship from the discharging to the outgoing shed. Granted that both decks of the Chelsea pier shed are used for freight, the upper for inbound and the lower for outbound freight, which is not always the case, the shed space is about two-thirds that of the Hamburg shed. It is confusing for a moment that the two-story shed does not make a total area of 200,000 square feet at the Chelsea piers as against 150,000 square feet at the Hamburg, or 140,000 square feet at the Bremen shed. The joker is found in the practice at the two Hanseatic ports of using different sheds for incoming and outgoing freight to avoid any possibility of confusion. Rather than warp the steamer across the slip or basin, the American practice has been to build double-decked sheds with the upper deck for incoming freight and the lower floor for outgoing freight. Such a pier shed is a more intensive use of the waterfront, but the cargo cannot be moved so easily. On the other hand, it is easier to move a ship in the European basins because of less current and easier angles. The quays are also provided with electric capstans for that purpose.

The Hamburg practice of shifting the vessel from inbound to outbound berths has the disadvantage of: (1) the cost in time and expense of shifting the vessel; (2) two berths are tied up for one ship. However, at Hamburg, most of the outturned cargo continues to destination by lighter to warehouse, or Elbe barge to interior points, and the berth space is needed for these craft. Here again there are local conditions that may not be repeated at another port. (3) A third disadvantage of shifting is that all hatches do not discharge at the same rate and the vessel cannot be shifted until all hatches have finished. But if the vessel is discharging to a second story while cargo is assembled on the first story, loading may commence as soon as any one hatch is ready to load.

Excessive Transit Shed Widths Increase Handling Costs.—The question of excessive width of the transit shed is serious in operating costs. It is cheaper and easier to move goods, wherever possible, direct from shipside to railroad car or to motor truck. If these distances are not excessive, a more liberal agreement may be made concerning the limits set for "shipside delivery," and a blanket rate for trucking to box cars may be agreed upon with the contracting stevedore at lower rates than to "point of rest on the wharf" and again from there to cars. Also above calculations are for extremely large cargo vessels. Large liners usually have little more cargo capacity, if as much, as small freighters, because the excess in size is taken up with passenger accommodations and equipment. Therefore, 10,000 deadweight carrying capacity is about the high-level average of cargo vessels at present (1925) and many cargo ships are smaller.

Furthermore, all of the cargo outturned from a vessel does not come to rest in the transit shed, but moves directly to lighter, cars, or trucks.

Therefore, a compromise must be reached between shed floor capacity and trucking distances depending upon conditions at any one port with regard to the percentage of freight loaded or discharged moving directly to rails, dray, or lighter. Table I (p. 54) will show the various solutions of the transit shed dimensions in the construction of many world ports. There are more 100-foot widths by far than 200-foot widths. The tendency seems to be to keep the width down to as near 100 feet as possible with full consideration of all factors involved.

Where subsoil conditions will not permit heavy structures at deep water, wider sheds are provided at the cost of longer trucking because of lower possible floor loads and because the back or inshore half of the shed is used for storage, as at New Orleans.

Harding's[1] Calculation of Shed Capacity.—It is a good rule to plan the shed for such a capacity that it will be possible to distribute all the goods taken from one ship berthed opposite to it.

When goods are handled by hand, the average height of tiering or piling is about 5 feet. It is, therefore, evident that there would be required a very large floor area to distribute and place a cargo of 6,000 tons according to the marks and cross-marks, especially in a miscellaneous cargo.

Assuming 60 cubic feet, instead of the marine 40 cubic feet, to represent the volume of 1 ton and 16 per cent more for distributing space, this would equal about 70 cubic feet per ton. Six thousand tons would, therefore, represent a cubical content of 420,000 cubic feet, and, at an average height of 5 feet, would cover a space of 84,000 square feet.

The reason for the 5-foot height for average tiering is that manual lifting above this height means a considerable increase in the handling expense. It is more economical to hand truck 400 feet than to lift 10 feet by man power. By mechanical tiering, freight can be tiered 20 or even 30 feet with little, if any, additional expense over tiering 5 feet.

Assuming an average height of tiering at 15 feet, a building could be made 56 feet in width, 500 feet in length, and yet have a capacity on the above basis of 6,000 tons, at 70 cubic feet per ton. In order to allow even more floor space for the distributing or a greater holding-shed capacity, 20 feet may be taken as an average tiering height. A shed, therefore, 60 feet wide, 500 feet long, and with a clear height below the girders of 30 feet, tiering 20 feet, would accommodate 8,500 tons, allowing 70 cubic feet per ton. This, or a shed 400 feet in length, would be a properly proportioned shed for inland river terminals.

It is interesting to note than 60 feet is the standard width of inbound railway freight stations.

If the width of the sheds can be kept within the above limits, the cost of the shed will be less than is usual, as there will be one short span only and no intermediate posts to interfere with the freight movements, which posts should be avoided if possible.

It is evident that capacity is secured by height and not by width.

[1] H. Mc. L. Harding, Consulting Terminal Engineer.

There are several points in which this calculation is open to attack. It is possible to tier standard packages such as bags, bales, and crates of uniform size, and of certain robust characteristics of packing or article, by well-known mechanical means at low expense. However, it is hardly possible to tier general cargo of all sorts and shapes of parcels except at great expense. Also, it is very difficult to handle small general cargo shipments to scattered consignees when the goods have been tiered. It would therefore seem that, except at wharves handling standardized cargo such as sugar or coffee in shipload lots for certain large consignees, it would be necessary to build sheds with a large unbroken surface to take the cargo of the usual line traffic spread out and not tiered.

Unbroken Floor Space.—Much of the confusion concerning pier layouts will be avoided by keeping firmly in mind the fact that the pier shed floor as calculated above does not include space for railroad tracks or teamways. The shed is a thing in itself and the relation of cranes, teamways, or railroad tracks to pier design or wharf layout is as an additional part of the equipment and not as part of the shed. These elements are discussed under other heads.

Deck Loads.—Furthermore, the load that the wharf will carry is a very positive limit to tiering or piling of cargo. Deck loads as low as 250 pounds per square foot occur where the foundation soil will not support greater weights. Few pile structures will carry more than 500 pounds to the square foot. Tin plate will overload a wharf with a height of 1 to 2 feet. Cotton is stored at shipside "on the head" and here the nature of the cargo and methods of handling prevent high piling. Many other kinds of cargo will not stand high piling as the excessive weight of the upper courses will crush and injure lower units of the pile. These calculations of Mr. Harding have only a very limited application to exceptional cases of subsoil and specialized cargo.

The Two-decked Transit Shed.—Contrary to the usual custom in European ports there has been a strong tendency towards the two-decked type of pier shed construction in America in recent years. There has been the need of more space, the need of keeping incoming and outgoing freight separated without moving the ship, and also the need of economy in waterfront along the congested portions of the cities. As American wharves on natural waters are not built along artificial basins which can be made to order with the proper amount of upland, the double deck has been the compromise.

Incoming and outgoing cargoes are given separate decks. Unless, however, there is absolutely the same connection by team and railroad to each deck from the level of that deck, there must be connection between the two decks. This connection serves to lower the degree of segregation of in- and outbound freight. It also involves much elevating and lowering from one deck to the other. These movements are accomplished by

goods lifts, or ordinary freight elevators, by spiral chutes and by continuous motion parcel elevators. There is no doubt that this between-decks movement is costly in time and labor.

The question of the double-decked transit shed is not so easily set aside. There is so much in its favor that most new wharves, either pier or quay developments, show two-decked transit sheds, from Los Angeles and Vancouver to Kobe, Osaka, Manila, around to the new Gladstone Docks, Liverpool, and the new municipal piers at Philadelphia and Norfolk. Norfolk and Los Angeles engineers say that with the good hardpan for their piles the additional deck doubles their transit shed

(*Photograph by the author.*)

FIG. 93.—Quay-pier with two-story stone shed at Vera Cruz, Mexico. Note landing platform or shelf, also standard and narrow gage tracks combined.

area at very little more expense. At Norfolk, an increase in the receipts by 10 cents a square foot a year for the upper deck will cover its additional cost. J. Wyman Ludlow of Los Angeles told the Port Authorities[1] that the extra cost of the second floor of a steel and concrete transit shed is between $2 and $3 a square foot of floor space gained thereby. Additional revenue of 2 cents a month the square foot would warrant the expenditure. At the prevailing rate for transit storage and demurrage (on cargo left beyond time limit on the wharf) the second story would receive its 2 cents minimum if occupied only 1 out of 5 months. It will be seen that the additional risk of the port investment for the second story is comparatively small compared with the many advantages in times of congestion.

[1] Thirteenth Annual Convention of the American Association of Port Authorities, 1924.

MULTIPLE-STORIED TRANSIT SHEDS

The Cresson system as proposed for Camden and Bayonne, New Jersey, and constructed at the Army Supply Bases at Boston and Philadelphia during the World War, introduces a new idea to American ports, that of the combination of transit shed and warehouse space. Every 600 feet along the bulkhead platform there are placed above the single-storied bulkhead shed two more stories to act as warehouse space. These are called storage sheds in contradistinction to transit sheds and to warehouses. Similar structures at Manchester are called transit sheds.

Experience has shown that it is necessary to provide for the storage of freight in addition to the short-time storage which can be accommodated in the bulkhead sheds. These storage buildings are generally similar in

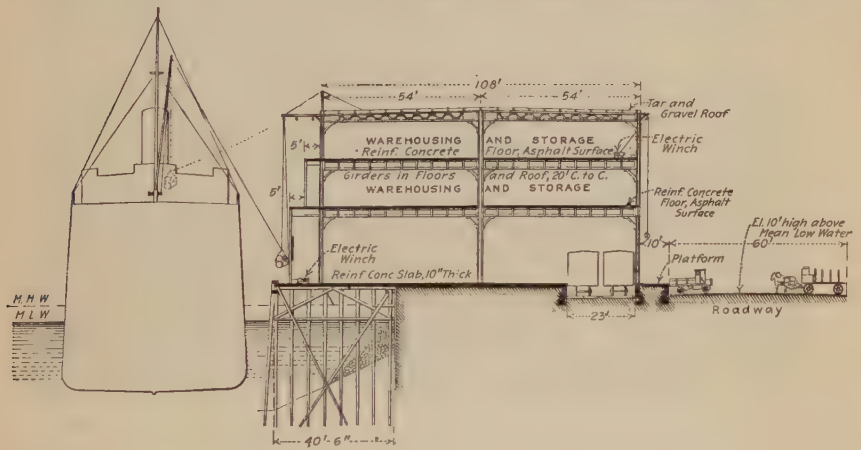


FIG. 94.—Cresson type combined transit and storage shed. A good arrangement for accommodating demurrage freight or other short-time storage (see also Fig. 156).

design to the bulkhead sheds, with many doors, and fully equipped with sprinklers, with no attempt at fireproofing the sides or the roof, and with cargo hoists or brackets to facilitate the handling of cargo. The storage shed is designed to accommodate demurrage freight, lost packages, and other cargo not removed promptly from the pier.

A notable departure has been made in the design of these sheds by setting back the shed on the second floor 5 feet from the line of the bulkhead shed, and by setting back the third-story shed 5 feet from the second-story shed, so that there will be a platform on which to land cargo and from which to receive cargo, and for operators. This practice, while it is not general in this country, is extensively used abroad. Many of the storehouses in London, for instance, are built in this manner.

The cross-section of the three-story shed is shown in Figs. 94 and 95. The lower floor will be for the protection of commodities in transit where they can be handled directly between ships and trucks and railroad cars.

The second and third stories extend over the railroad tracks and are intended for storage and warehousing. The 10-foot platform to the rear will make it possible to handle commodities between the warehousing and storage floors and railroad cars or trucks without their coming into the pier sheds at all. This is a rather novel design and, it is believed, will effect economies in storage. Commodities can be taken from ships and stored and then loaded into railroad cars or into trucks, without the necessity of any intermediate drayage, and without having to pass through a congested pier or bulkhead shed.

The Cresson storage shed is valuable for accommodating demurrage freight or freight which for some reason or other must wait longer than 48 hours and must put some place out of the way. At New York and elsewhere demurrage freight is carted to warehouses and the expense is charged to the shipper by the transportation company (steamship or

FIG. 95.—Philadelphia Army Supply Base. Multiple-story transit sheds. Cresson type—transit storage shed (see Fig. 156 for cross-section).

railroad). These charges amount to millions of dollars a year, an expense which would be reduced to a minimum by some such plan of accommodation. On the other hand, no one should be misled into thinking that general cargo destined for warehousing would be loaded from ship's hold to warehouse deck in any such simple manner. Like every other such plan the Cresson storage shed is a welcome innovation to accomplish a very definite and circumscribed piece of work.

The storage shed of more than two decks, as described in the case of the late B. F. Cresson's sketches for Camden, subsequently found two principal opportunities for demonstration: the Navy Pier in connection with the Army Supply Base at Boston and the Army Supply Base at Philadelphia (Fig. 95). Both of these installations were designed under the influence of Mr. Cresson while special advisor to Colonel Wells, Chief of the Division of Storage (P. S. and T.), under General Goethals as Quartermaster General during the World War. It will be noted that both of these terminals are carried out on the principle of a large pier

structure of the quay-pier type. Several different theories of layout are incorporated in designing these terminals. For instance, the wharf apron or string piece varies in width on different jobs. The face of the three-deck shed of the Philadelphia Base is vertical on one side, but stepped back approximately 7 feet in each story on the other side of that base. The Boston Base carries a narrow landing balcony or gallery.

Manchester Sheds (Fig. 96).—The influence of multiple-story transit sheds at Manchester is clearly seen in these recent American works. The type at Manchester includes both three- and four-story transit sheds.

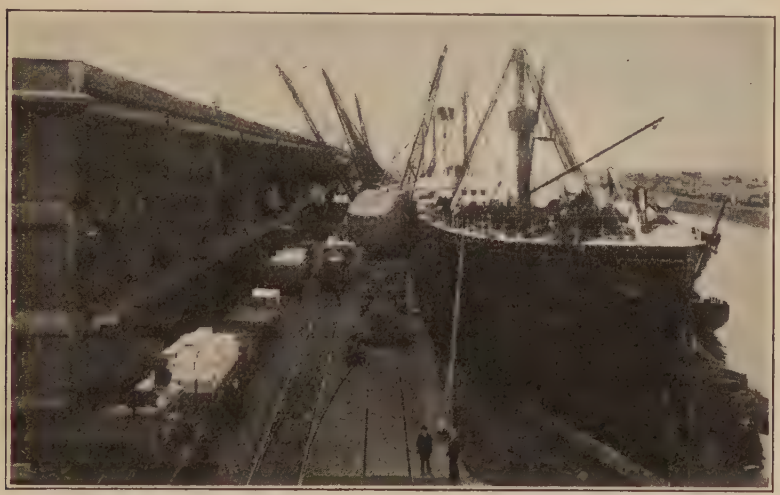


FIG. 96.—Three-story transit shed, Manchester. At this port the one-story warehouse and the multiple-story transit shed are preferred. Note concrete landing ledge on second floor and hinged ledges on third floor.

At Manchester it is not considered that these are warehouses and the point is maintained that these quay-side structures are intended only for goods in transit and not for warehousing. In this connection, under the chapter on warehouses, a strict differentiation will be made between transit storage and merchandising storage, inasmuch as transit storage may be of considerable time above the 48-hour period and still be caused entirely by the exigencies of transportation, while a merchandising warehouse has to do with the buying and selling of commodities and the holding of commodities in storage pending merchandising operations.

At the properties of the Manchester Ship Canal Company, Marshall Stevens, M. P., expressed his view to the writer that the single-story *warehouse* is undoubtedly more economical in construction and in operation than the multiple-story *warehouse*, although the reverse may be true with regard to shipside *transit sheds*. This conclusion is exactly opposite to present American tendencies where we build low transit sheds and high warehouses.

At Vera Cruz, Mexico (Fig. 93), there is to be found an almost identical type of multiple-story transitshed to serve that transshipping point from the ship to the railroad for the interior. As at Manchester, merchandise is held in various floors of the multiple-story shed as the cargo is unloaded

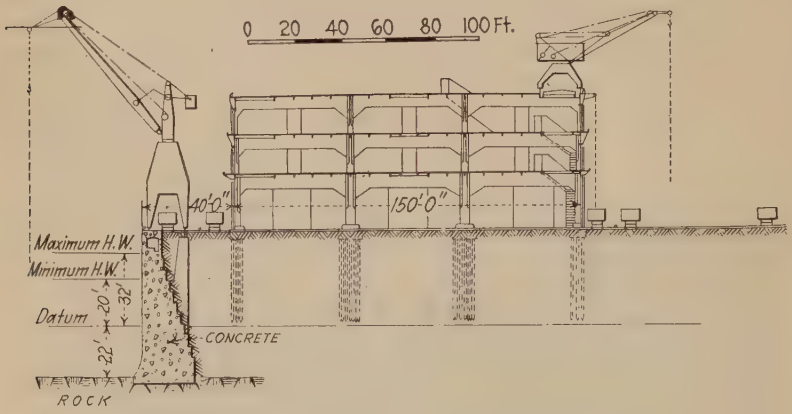


FIG. 97.—Treble-story transit sheds of the new Gladstone Docks, Liverpool.

by cranes from the ship, until such time as it is necessary to load them into cars for shipment to Mexico City and way stations.

The sheds at Gladstone Docks, Liverpool, and Freeport Malmö are very recent examples of three-story transit sheds (Figs. 97 and 98).

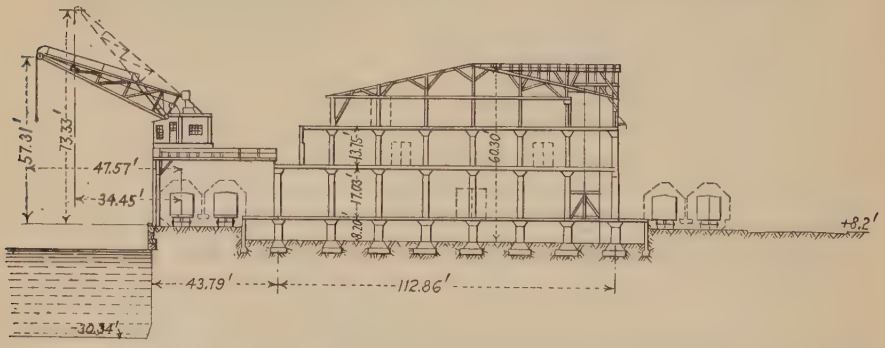


FIG. 98.—Malmö Free Port. Triple-story transit shed-warehouse, width, ground floor 34.4 meters (112.86 feet).

The Single-story Shed of Sufficient Width to Offer Space for Transit Storage.—Having followed the transit shed through various forms from one to four stories in height and back again to the single-story shed, another point can now be rather clearly seen. The 48-hour rule must be enforced in transit sheds on narrow piers because the area is not sufficient to carry the cargo of even one vessel. It is therefore necessary

to enforce removal to a warehouse even if at considerable cost to the merchandise. The multiple-story shed is used in an effort to increase the amount of floor area at ship side in order to afford merchandise in transit a longer storage period in view of the fact that it is impossible in 48 hours to make disposition of all the merchandise outturned from any ship. Therefore, with a view to the cost of construction, *i.e.*, the amount of interest to be earned annually on the capital investment, and to the increased costs of operation, if any, of the multiple-story shed, the idea occurs that, if not too cramped for land and by high land values, the solution is in widening the single-story shed to such a point that the front or ship-side portion of the shed may be ample to accommodate cargo to be worked in connection with any single vessel while the inshore part of the shed on the far side from the water can easily accommodate a considerable amount of merchandise pending further disposition. With the development of the inner trucking facilities, this in-transit storage on the inshore side of a single-deck transit shed may be the correct solution of the in-transit storage problem. This development, however, would be only at terminals with a large percentage of local deliveries and a small percentage of through rail freight, otherwise the trucking distances, ship to car, would be too long. This system should be applicable in all harbor and port development where ample area may be procured at a reasonable price. The modern port is usually made new from the ground up on some swamp or lowland area of low land value. Given these conditions, under the control of a port authority developing the property, the basin and quay system with wide, single-story transit sheds of sufficient depth to afford ample room for working of cargo of the ship at the berth, and at the same time additional space in the rear for storage in transit over reasonable periods of time, seems to offer the best solution of cost of construction and cost of operation. An increasing charge for such storage after 48 hours, 15, 30, 45, 60 days will be necessary to expedite disposition of merchandise; otherwise a congestion similar to that which occurred at Havana, Cuba, may be expected.

This method has also been successfully applied at Havre, Bremen, and many other ports. At New Orleans, with wide sheds, a roadway passes down the center line of the sheds; the half of the shed floor towards the water is ship-side storage while the side toward the shore is used for longer periods.

Construction Materials.—The question of materials and strength of materials in shed construction is a large subject belonging entirely in the field of structural engineering except as already discussed from the point of view of maintenance. The planning and operating engineer is interested in layout to facilitate economical operation and construction that will strike a balance between annual interest on the bonds and cost of maintenance as part of operating cost. Put another way, operating

cost consists of interest, depreciation, maintenance, and payrolls with good will added from the high service rendered shipper and carrier.

Some of the usual shed types are as follows:

Frame	Sidewalls	Roofs	Floors
F. Timber	Corrugated steel	Corrugated steel	Planking
E. Steel	Corrugated steel	Corrugated steel	Planking
D. Steel	Metal lath Granite concrete	Corrugated steel	Cement
C. Steel	Fire brick fill	Tar pebble	Cement-asphalt
B. Reinforced concrete	Fire brick fill or concrete slabs	Tar pebble or patent bituminous	Cement-asphalt
A. Reinforced concrete	"Fenestra" or other steel frame fire glass lighting	Tar pebble or patent bituminous or slate	Granite cubes

These combinations are varied in practice and may be multiplied as to variety and combinations, but they summarize the principal types in current use.

ILLUMINATION OF PORT TERMINAL SHEDS AND YARDS

Artificial Lighting of Interiors.—Quoting from the *Edison Lamp Works Bulletin*, L. D., No. 111, page 6:

In an investigation of fifty-eight large steamship piers in New York City, as regards the artificial lighting, data were obtained on the size of the pier, number and size of lighting units, spacing and height of lamps, height of ceiling, color of walls and ceilings, class of traffic, watts per square foot, and general artificial lighting conditions.

The investigators were experienced illuminating engineers competent to evaluate the resultant illumination. An analysis of the results showed that 6.2 per cent had good illumination, 51.2 per cent fair illumination, and 42.6 per cent illumination which was entirely inadequate and generally poor. The average watts per square foot of those piers electrically lighted was 0.16, with a maximum of 0.34 and a minimum of 0.05. Very much better illumination results would have been obtained in practically all the cases if the equipment had been well maintained and surroundings given an occasional coat of whitewash or other light paint. Three and six-tenths per cent of the piers had white walls and ceiling, 9.1 per cent light-colored walls, 20 per cent medium-colored walls, 52.8 per cent dark, and 14.5 per cent very dark (almost black) surroundings.

The above data justify the foregoing criticisms. Such conditions would not be tolerated for the handling of materials in ordinary manufacturing plants, and the surprising feature is that it has been possible to get along at all with such poor light.

A classification might be made of the principal divisions into which terminal lighting may be considered. These are:

Lighting of interiors, such as pier sheds, warehouses, etc.
Lighting of pier decks.
Lighting of unloading operations.
Handling of bulk material, such as coal, ore, etc.
Railroad yards.
Special application requiring flood lighting or projection equipment.

The problem of interior lighting for sheds and warehouses has been studied among others by H. E. Mahan from the Illuminating Engineering Laboratory of the General Electric Company. The results of his studies are extremely interesting in all port development plans. The fundamental considerations may be summarized as follows:

1. Glare must be eliminated.

2. Dark shadows and too great a variation in intensity of illumination must be avoided through diffusion and distribution of light. It must be borne in mind that dark shadows create an accident hazard, a pilferage hazard, and make identification of packages difficult.

3. Intensity of light should be ample to permit convenient reading of labels, to facilitate efficient and accurate operations. Suggested intensities of light for various purposes are:

	Average Foot Candles
Warehouses	2 to 3
Pier sheds (storage area)	2 to 3
Pier sheds (driveways)	0.5 to 1
Unloading bulk material	0.5 to 1
Unloading package material	1.5 to 2
Railroad yards	0.025 to 0.05

4. The proper voltage should be supplied to incandescent lamps to operate at their rated efficiency. A change of 1 volt causes a change of 3.5 per cent in the light. The light and the power lines should be from separate feeders, otherwise the operation of a crane will cause fluctuations in the light. Also a separate line will insure continuation of illumination in case an overload on the power line blows a fuse. A 110-volt lighting system is superior to one of 220-volts.

5. Frequent cleaning is necessary to maintain proper illumination efficiency. The rapid collection of dust and dirt on lamps and reflectors will reduce the illumination as much as 50 per cent within a comparatively short time. In a large terminal, the entire time of a lamp washer could well be employed as he would come around again to the same lamp about the time it needed attention.

6. A mill-white finish of the interior of sheds and warehouses will pay for itself in increased illuminating efficiency.

As to the color of the pier sheds, it is pointed out that white is the more efficient color for lighting, but liable to become dingy very soon. It is suggested that up to 10 feet the walls could be a darker color of gray or yellow and the upper walls, roof, and roof girders painted white.

Advantages of Well-lighted Terminals.—Proper illumination is conducive to fewer accidents, less damage to goods, greater speed of operation, greater ease in eliminating rodents, and more effective police supervision preventing pilferage. Proper lighting increases the efficiency of the men at work, in particular, night shifts. It has been well established in industrial plants that proper lighting will increase efficiency of production from 10 to 15 per cent. Proper illumination is very essential to free ports or bonded warehouses.

Artificial Yard Lighting—Outdoors.—The problems of illumination of marine terminals are essentially the same as those of railroad terminals. The experience of George T. Johnson, the electrical supervisor of the New York, New Haven & Hartford Railroad, will give a foundation for consideration of the problems of lighting the open spaces and yards of marine terminals, including the wharf apron and handling areas. This experience may be summarized briefly.

Until 1912, the yards were illuminated by a series of multiple arc lamps placed at convenient points and above roundhouses and coal pockets. This system was good as far as it went, but expensive. Cluster lighting with carbon filament lamps was tried, but was unsuccessful. Tungsten lamps of large wattage were introduced when it was found that the filaments had progressed in manufacture to a point where they would withstand vibration. These gave excellent results with lower current consumption than the arcs. The reflectors first tried were unsuitable for outdoor use and the first wind storm blew them from the fixtures. A good porcelain enameled shade was then introduced. These are durable but suffer deterioration from locomotive gases. Still no attempt was made to light the entire yard. The application of the so-called flood light was then tried, a type of lamp using a standard 1,000 watt lamp and a silvered glass reflector that would spread the rays in a way to prevent glare and yet give sufficient light. The illumination was effective for a distance of 500 feet for a single lamp, the spread being 40 feet per hundred. The lamp looked much like a locomotive headlight. These gave excellent results on construction jobs.

The main impetus to more effective lighting came with the necessity for military protection and supervision of terminals during the war. This same situation applies always at marine terminals to prevent pilferage. The first installation on the New York, New Haven & Hartford at the Poughkeepsie bridge over the Hudson, a point where the river is more than 2,000 feet wide, was very successful, the entire installation costing $1,500. The reflector used had a range of 600 feet. Shorter distances were illuminated by more open types of shades that are now used extensively in illuminating billboards and public buildings.

In lighting classification yards, it must be remembered that a hump and ladder classification yard moves the traffic in one direction. It is

therefore possible to work in the same direction as the rays of light and not facing the light. In the classification yard, beginning with the ladder track from the hump, seven lamps on poles 250 feet apart were installed that gave excellent results. Advantages were taken of any buildings in the vicinity to install additional lamps. In other lighting, such as power plants, machine shop, roundhouses, storehouses, office buildings, ash pits, coal pockets, etc., 50–watt lamps in shallow bowl porcelain enameled reflectors were installed.

It is necessary to avoid overhead wires and the lighting wires were run in creosoted wooden ducts placed underground. In the receiving yard, which is electrified, the trolley poles carry a 1,000-watt flood lamp at distances of 600 feet.

In more confined places, such as transfer platforms, which correspond to the wharf apron, car-loading platforms, and other working spaces of a marine terminal, the lighting is accomplished by two lines of 25-watt lamps spaced 20 feet apart and about 5 feet from the edge of the platforms. The platforms are 1,200 feet long by 30 feet wide. The lamps are turned off and on by switches in the office building, putting the control under a responsible head.

Artificial versus Daylight.—It is usually cheaper to light a shed or a warehouse artificially than to install a large number of fire-glass windows. In the case of wide double-deck piers, the interior of the shed will require artificial lighting because the windows will be small and a considerable distance from the center of the shed.

Daylight Lighting.—However efficient artificial lighting may be, every effort should be made in the construction of transit sheds to design the shed with the maximum amount of windows. The entire space above the doors and above the marquise or canopy over the loading platform should be windows, although these windows may be only 2 or 3 feet high where low-roofed trusses are provided in the design.

Lighting Single-story Sheds.—This is less difficult than in the case of multiple-story sheds, but the single-story sheds are usually much wider than the higher structures. One example has been given in discussing maintenance, namely, glass tiles at frequent intervals. This method is not applicable to American practice as we use bituminous roofing in most cases.

The Hamburg method (Fig. 99) of illuminating the middle of a large shed is practical and efficient. This may be termed the "cathedral" design corresponding to the nave and two aisles of a cathedral, the center one of the three longitudinal bays having a high clear-story roof admitting a flood of light through the windows that occupy all the space between roof supports. This construction leaves free the roofs over the aisles (outer bays) for a boardwalk, passenger landing, or other similar public benefit (not so used at Hamburg, however). This cathedral

type of lighting supplements the usual glass panels of the outside walls, between and over doors. These are essential to the illumination of the aisle bays.

In many-storied sheds natural lighting is difficult. Every available space in the side walls should be glassed, preferably with light deflecting

FIG. 99.—Good light from high, clear story of middle bay, transit shed No. 75, Kronprinz Quay, Hamburg.

glasses such as Luxfer Prisms, that will conduct the light rays back into the shed.

It is certain that much too little attention has been given to natural and artificial shed lighting and this subject deserves much more discussion than can be given here.

CHAPTER VIII

TRANSIT SHED EQUIPMENT

The movements in the shed consist of sorting, delivery to trucks, drays, cars and lighters, and tiering. All this handling is the source of the largest items of expense. It has just been shown above that with ship's tackle the cost of transferring need not be more than 5 or 6 cents a ton, and with cargo mast or cranes much less. Some recent and authoritative cost calculations, of handling after the freight had been set down on the wharf, from the progressive Port of Seattle, are instructive.

The average cost of handling Japanese and Chinese merchandise from ship's sling into wharf and piling and sorting is estimated to be 60 cents per ton of 2,000 pounds. For handling gunnies, shellac, hemp, and similar articles from India it is 50 cents per ton. Coastwise Alaska traffic consisting of miscellaneous merchandise costs about 30 cents per ton. Traffic rates published by railroad companies for this class of work run to about 25 cents per ton, while private and steamship wharves charge a higher rate.[1]

(Photograph by the author.)

FIG. 100.—The hand truck, the all-around *bonne a tout faire* of terminal operations. Two rows of box cars spotted with doors registering at a wharf in Duluth, Minnesota. Lake-rail package freight.

The Hand Truck (Fig. 100).—The chief equipment in freight handling is the hand truck. All efforts are being directed towards the substitution of mechanical means of handling freight on the pier to reduce the numbers of truckers. Much more improvement will be made if the inventors do not insist on evolving something to do everything with the result that it does nothing well. Our besetting sin is in trying to make one machine a *bonne a tout faire*. For short movements of general parcel freight the hand truck cannot be dispensed with. When the movements are longer than 150 to 200 feet, then is the time when other machines should be

[1] Statistics furnished by MR. FORMAN, Assistant Manager of the Port of Seattle, 1918.

introduced to take the burden and waste of the long haul away from the hand truck. For moving parcels of all sizes and conditions over short distances nothing to date has been sufficiently flexible to be worth while. Therefore let us keep the hand truck for its flexibility and make it work in conjunction with other mechanical appliances which will handle freight over longer distances and when it is exceptionally heavy.

The Electric Truck.—Much attention has been attracted during the past few years by the electric storage battery truck. There has been severe criticism of its performance and much opposition to the innovation. This may be due to several things. The manufacturers, of whom there are several in the United States, have claimed too much for the truck, have tried to make it do too many things, and the users have been disappointed. The electric truck has been used on very rough piers where the rather small wheels have been unable to overcome the unevenness, and breakage has resulted. In similar manner the ramps into cars and onto gangplanks have been too steep and the joints too rough for the small wheels. It is seldom possible to have the "one man-one truck" organization which would make the workman in charge of a truck responsible for its condition. New men each time will have neither skill in operation nor interest in the truck. Then there has been the practice of joyriding instead of walking from one end of the wharf or pier to the other. The principal failure is due to overloading. Trucks have been ordered which were too small for the duty required. There is no economy in overloading any machine, especially storage batteries. During the World War several thousand electric tractor trucks were installed by the United States Government in various terminals and are still rendering good service.

(*Photograph by the author.*)

FIG. 101.—A storage battery tractor (trackless train) at the South Brooklyn Army Supply Base.

Trailers.—The best hope for the electric truck, in addition to regular operators and smooth decks, is in the entire operation of the trucking. As in the case of the automobile truck the machine is losing money for the owners when it is standing still. Several efforts have been made to eliminate the waiting loss by either trailers or removable bodies. If the work of the truck is to move freight from the pier to the head house for loading teams, or for other long hauls, one motor can keep three trailers occupied, one loading, one underway, and one unloading.

Skids.—The other principle is that of the removable body. A skid is constructed of stout framework with legs which enable the electric motor to run under it and lift it with its load. Many of these skids may be used. Goods are piled on them when sorted and held that way in storage until they are called for. The electric truck simply lifts the waiting load and carts it to the waiting dray. In the local movement of loading the skids in the first place and parking them properly to be picked up later the reliable old hand truck does its accustomed duty. The only difference is that the freight is sorted and stored on skids instead of the floor and therefore can be picked up later. It is evident that this system requires considerable shed floor space.

A compromise with the hand truck is the hand platform truck or low pushcart, which is a skid on wheels. It will be picked up by the electric truck in the same way.

There will still be many queer parcels which cannot be handled by these small standardized skids and will have to be moved by hand trucks as formerly. The large majority of general cargo, however, can be handled this way at a great saving.

It is evident from the foregoing that the hand truck or the wheeled platform will work within small radius. The economy of the electric truck will be in the long haul and in keeping busy along the route. The freight on the shed floor should be arranged with this in view and the motor itself kept moving.

Everything still remains to be done in the scientific investigation of the economies of such equipment. There is an endless field for the work of scientific investigators. Engineering and economic seminars will find material for investigation for many years to come. In the meantime, until accurate records are kept, until stop-watch and pedometer measurements of freight movements have been tabulated, we can rely only on what data the manufacturers are able to collect. In lieu of these unbiased and scientific data, which future students must collect and tabulate, may be appended some statements from some of the manufacturers which, although honestly intended, cannot be considered coldly scientific data.

Table of Electric Truck Economies as of April, 1925.—The most recent calculations of electric truck economies available for this study are found in *Management and Administration* for April, 1925.[1] The summary table is added. The story is not new but the figures are. Since the writer's first discussion in 1917, wages have doubled and the spread between hand labor and mechanical equipment has increased. This spread may be expected to widen as the years advance (Table IV).

[1] HAGEMANN, GEORGE E., "21 Material Handling Installations Which Have Saved Money; Striking Data on Trucks, Tractors, and Cupola Chargers."

TABLE IV.—DATA ON ECONOMIES OF VARIOUS TYPES OF EQUIPMENT

(Comparisons with hand methods or semimechanical equipment given where available. In other cases operating data only are tabulated)

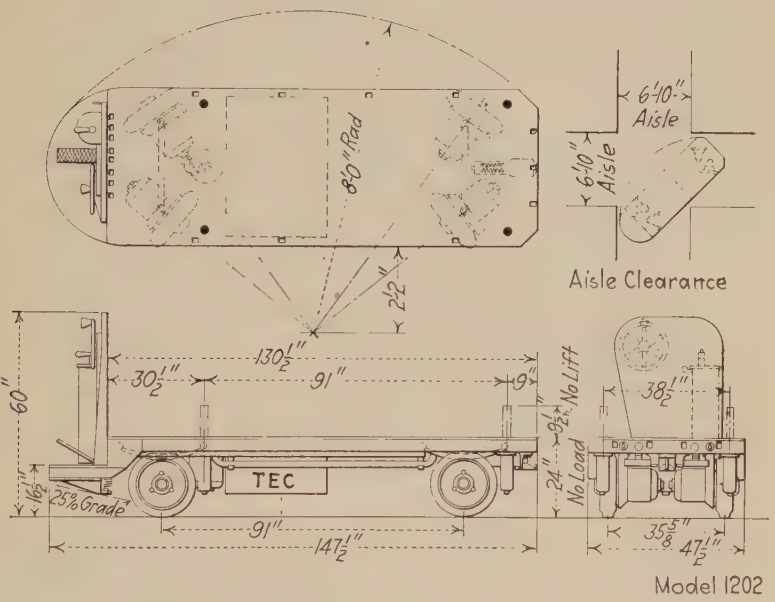
Item	Type of apparatus	Plant where installed and date	Make	Handling service for which used	Number used	Loads handled	Men required	Men for hand methods	Cost of handling by hand	Cost of handling by equipment	Total savings by use of equipment per year	Additional advantages credited
1	Lift truck	Northwestern Yeast Co.	Barrett-Cravens	Boxes and shooks	.....	.....	1	.....	.....	.....	$900 per truck	
2	Tructractor[1]	Universal Winding Co., 1923	Clark	Sprues and foundry refuse	1	1 ton	2	6	$6,706.00	$3,578.84	3,127.16	
3	Tructractor	Mason Machine Works Co., 1919 and 1922	Clark	Castings	2	Up to 3,000 pounds	1	4	4,957.20	3,304.80	1,652.40	
4	Tructractor	Blackmer and Post Pipe Co.	Clark	Coal	1	1,500 pounds	1	.....	.....	1,762.70[2]	.....	Saves congestion
5	Tructractor	A large pottery plant, 1918 and later	Clark	Coal, clay, etc.	6	1,300 to 1,800 pounds	5	.....	.....	0.678 per mile	.....	Simplifies material handling
6	Duat tractor	Crooks Terminal Warehouse	Clark	Freight	1	6 trailers, or 15,000 pounds, etc.	7	6	0.282 per ton	0.125 per ton	0.157 per ton	Cuts handling time to one-third
7	Tier-lift truck	J. Manz Engraving Co.	Lakewood	Paper	1	4,000 pounds	4	10	1.07 per ton	0.50 per ton	0.57 per ton	
8	Tier-lift truck	Hummel and Downing Co.	Lakewood	Rolls of paper	1	Two 1,300 pound rolls	1	4	0.10 per roll	0.02 per roll	0.08 per roll	Double storage space
9	Tier-lift truck	Passaic Metal Ware Co.	Lakewood	Tin plate	.....	.....	5	15	0.64 per ton	0.24 per ton	0.40 per ton	
10	Tier-lift truck	Barrett Co.	Lakewood	Barrels, bags, drums, etc.	.....	.....	5	9	.....	.....	.....	Saves considerable time
11	Tier-lift truck	Detroit Free Press	Lakewood	Rolls of paper	.....	1,890 pound rolls	2	5	.....	.....	25 per day	Saves time, doubles storage space
12	Tractor	Western Warehousing Co., 1920	Mercury	Freight	.....	.....	1	5	7,722.00	2,240.19	5,481.81	

[1] Equipment cost: Items (2) $1,600; (4) $1,700; (5) $1,600 each; (6) $1,000; (12) $2,050.

[2] This is exclusive of shoveling when loading. Cost per ton, excluding shoveling, is $0.13; including shoveling, $0.305.

Electric Truck Developments, 1917–1924.—In recent years, since the first efforts were made to develop mechanical handling and trucking in terminals and warehouses, there have been several refinements of the electric truck that are of interest.

The extended use of electric trucks together with the invention of the automatic or microleveling elevator on large elevator platforms has brought about an increased use of: (1) tractors and trailers; (2) many-



(Terminal Engineering Company, Inc.)

FIG. 102.—Model 1202—specifications. Capacity 5,000 pounds. Speed ½ to 10 miles per hour, light; ½ to 7 miles per hour with full load. Clearance radius, 8 feet, remarkably short considering the 12-foot 3½-inch patents. Individual motor on each wheel driving direct through double reduction internal gear. Motors, four standard, series-wound, 60 volt, G. E. motors on wheels and one of identical type on elevating jacks. Tires, 20″ × 5″ solid rubber.

story warehouses; (3) internal or shaft elevator as compared with whip hoists outside the building.

Together with these developments there has been noticed the marked growth in the use of either platform lift or tractors and trailer types for movement between ship side and adjacent warehouses and the decided opinion that warehouses for transit or merchandise in storage should be within electric truck distance of ship side.

To meet this end and also to provide for short turns through narrow aisles in warehouses and transit sheds, there has been developed a larger and faster truck platform lift type with larger wheels and more power. One of the most interesting types developed by the Terminal Engineering

Company in New York is driven by four separate motors, one for each wheel, and each wheel turns on its own pinion in order to give a turning radius of 8 feet for a truck with an overall dimension of 12 feet, 3 inches. The idea is that a larger truck still capable of navigating narrow aisles and short turns can make deliveries from ship side to warehouses within distances up to half a mile with dispatch and yet with economy as to wear and tear. With three bodies for each TEC truck the half-mile radius can be served with one flat rate because the running time for 1 mile round trip will equal loading and unloading time of bodies at both ends of the run. Shorter runs would involve a corresponding waiting time, therefore no less cost except for power, which is insignificant. It will be seen, therefore, that warehouse layout, road and platform construction, elevation, and the vehicle itself are all undergoing progressive changes towards a general utility coordination of the interior trucking situation (Fig. 102).

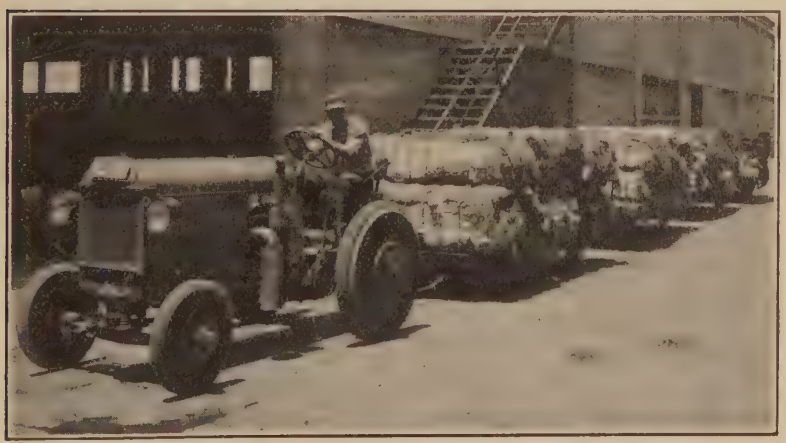
Arthur King, Director of the Port of Norfolk, where much cotton is handled, has worked out the dimensions of a low, wide, platform trailer for handling bales of cotton that will permit a bale of cotton standing on end to be pushed with one movement over onto the platform, the platform being just high enough to have the cotton fall in place and long enough to accommodate three bales a trip. This is an example of refinement of the platform to accommodate the peculiar conditions of the predominating cargo of the transit shed. A similar cotton bale trailer is shown in Fig. 104 at New Orleans.

Gas Tractors (Figs. 103–104).—Those who have visited the Ford automobile plant were impressed by the rapidity with which Ford chassis mounted on truck wheels as tractors make deliveries about the great plant. Also Fordson tractors with solid rubber tires are used with trailers. The objection to internal combustion engines on wharves and in warehouses was based primarily on the fire hazard due to carbon sparks passing through the muffler, and for this reason nearly all internal combustion motors have been ruled off the piers by the underwriters. But a water muffler has been developed avoiding the spark hazard, and several firms have been constructing internal combustion tractors for use with trailers. The advantage of the automobile tractor is found in the greater speed, more rapid pick-up, greater power, and lower cost. One firm says for its tractor:

> You will be interested in knowing the experience of the East Waterway Dock and Warehouse Company and Frank Waterway and Company with Prescott tractors at their Seattle docks. They installed five of our machines to replace a large number of electric machines, and as a result, are able to do without the services of eighty-nine hand truckers whose average pay was $6 per day. These companies have since increased this equipment to ten machines handling Oriental oils and other products.

The Commodore Point Terminal Company and the Municipal Terminals at Jacksonville, Florida, are using Fordson tractors with satisfaction. The International Harvester Company has a wharf tractor

FIG. 103.—Gasoline tractor with water muffler, municipal terminals, Jacksonville, Florida, January, 1925.



(Courtesy of Bradford, I. H. C.)

FIG. 104.—A McCormick-Deering gasoline tractor in wharf work. Note lights to be allowed use of city streets to operate to near-by warehouses.

similar in appearance to a Fordson. Some advantages of the gasoline tractor are: First costs are lower by one-half—the tractive force is greater: speed is greater; wheels are larger, therefore less restricted to smooth

pavements; constant operations without recharging; it can be used for shifting freight cars on wharf. However, the electric tractor is simpler, quieter, has smaller turning radius and longer life.

Steady progress is being made toward the greater use of machinery for handling freight in terminals.

Imports Subject to Duty and Weighing.—One example of inefficiency is found in handling imports subject to duty. Here is a case where one of the above-mentioned trucking improvements would certainly accomplish a large saving. Take raw sugar as an example, as handled at North Atlantic Ports.

1. Raw sugar imported is hoisted from the hold of the ship in slings.
2. Lowered onto small platform hand trucks.
3. Moved by man power a short distance and piled on deck of the pier. The cargo must be gotten away from the fall of the ship's sling.
4. Handled by government men onto government scales.
5. Handled from the government scales to the merchants' scales.
6. Loaded onto trucks and moved to warehouse, drays, customs, and railroad cars.

The remedy for the waste movements of (3), (4), and (5) would be to adopt a standard platform truck with the weight of the same clearly marked on it. Then this truck would move onto government platform scales. The tare would be the weight painted on the truck. Merchants should agree to accept the weight of the customs officials. After weighing, the truck would continue its course to the place of loading into the railroad cars or other conveyances. This system would eliminate many laborers and all the handling at the scales and also the second weighing.

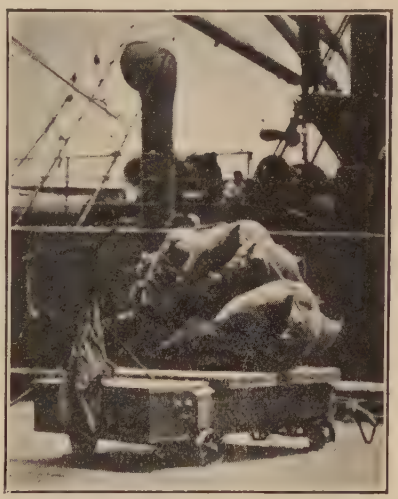
Government, merchants, warehouses, and ship lines would save much time and money by cooperating in the standardization of handling equipment to increase the ease and speed of handling and clearing through the customs.

In the case of electric trucks with trailers, the trailers would be used on the scales and not the tractor itself, because of the changes of weight in the elements. The trailer could be made so inaccessible that the chance of tampering with its weight would be reduced to the vanishing point.

There are also simple hand trucks, made to slide under a platform and to lift it by one motion so that it can be rolled to the place desired on the pier deck. The drawback to their use is that the small wheels are inefficient and require great tractive force, even on a smooth floor.

Weighing and Dispatch.—Many commodities must be weighed as discharged for reasons of commercial or customs practice, such as raw sugar in bags, fertilizer materials in bags, nitrates, kainite, potash, and many others. The rapid dispatch of the ship is dependent upon the method of weighing as this weighing is apt to be the bottle neck in the

operations. Weighing is a separate operation, and a weighing fee is collected in addition to the stevedoring rates. In fact, weighing is often done by a different contractor; by licensed and bonded weighers. The old, established method of weighing fertilizer materials in bags is at the point of deposit at ship side on small platform scales (Fig. 105). In this method the sling load of ten bags is lowered directly onto the scales from the hold, weighed, and then the bags pulled off onto the hand trucks of waiting longshoremen. This is indeed quicker weighing than elsewhere, notably New York, where weighing is done with weights on a balancing arm scale, in use since the Hanseats.



(*Photograph by the author.*)

FIG. 105.—Old-fashioned scales for weighing at shipside, a method that holds up the discharging of the ship.

A clocking of the cycle of several examples of the ship-side weighing showed 1 minute 30 seconds. But upon analysis, it was noted that the hold gang broke out and slung, and the deck crew transferred each draft in 25 to 30 seconds, the draft hanging for a minute or longer, and each cycle waiting for the weighing to be finished and the draft on the scales broken up and removed. In other words, the ship's discharge was three times longer than would have been necessary if not delayed by the weighing. Therefore, the ship required 9 days to complete discharging when it could have been accomplished in 3 days. The weigher or the contracting stevedore paying the shore gang of hand truckers must lose money because, during the weighing, some six to eight truckers are standing by idle, waiting for the weighing. This waiting may be as much as 1 minute a draft for six men. As both weigher and contracting stevedore pay their longshore labor by the hour, but receive their revenue by the ton, the question of hanging drafts or waiting truckers is of vital profit and loss concern to them, as well as to the ship and to the wharfinger, who could handle two or three more ships in the meantime.

The remedy is to be found in some system of automatic registering, tare-deducting platform scales, located away from ship-side. Such scales cost from $800 to $3,000, which is the cost of the electric scale. In this system, each draft is deposited, sling and all, onto a wooden platform (also called skid, bench, buck, tray) or trailer truck. These are of known weight. They are picked up at once by a platform-lift electric tractor (Fig. 55), or a simple trailing tractor (Fig. 56), and taken away from

shipside to the weighing platform. Deposited on this or pulled onto it, the scales automatically record the weight deducting the tare of the equipment. The loads then pass on to the waiting railroad cars or to the pile for tiering. By increasing the speed of weighing without handling and away from ship side, there will be no hanging nor waiting time. The point of deposit at ship side being free for platform or trailers, several can be in constant readiness and each draft deposited as it comes from the hold onto one of the platforms. Also with space available between ship-side and the scale, another reservoir is created to take up slack, or irregularity of time at the scale.

The difficulty encountered, of introducing such improvements against the inertia of old, established customs, is surprising. One claim by the old timers is that platform scales are inaccurate. But good scales carefully adjusted are even more accurate. The tare can be carefully determined for each individual platform or trailer and its weight marked on the side. A factory product, however, will weigh almost exactly the same for each trailer and will average to the ounce for the full quota of equipment.

Opposition to improvements in weighing comes not only from licensed weighers, who fear to lose some present business, but from lesser government officials. The late Mr. Briggs of the Bureau of Standards was an ardent advocate of improved weighing, but in the Bureau of Customs of the Department of the Treasury there has been continued aversion to change. The principal obstructionist is the "Engineer for Electrical Weighing," who construes his title as limiting his jurisdiction to that single type of mechanical scale. Anything in Washington can be changed by determined effort through the elected representatives of the people, including senators. That is our system of representative government and should be used.

Some weighers still insist upon the old tripod balance with beam and weights. This is even slower than ship-side scales. Also not necessarily more accurate. In Bergen, Norway, at the old Hansa Hause, for centuries the headquarters of the Hanseatic League, two sets of weights are shown the visitor, that were in use for several hundred years, one set to use on the beam balance in buying merchandise and the other set to use when selling.

Weighing mechanisms and systems are very important items of wharf equipment in terminals handling special cargoes.

It might be added that longer delays are suffered when the importer, not having sold the cargo, holds up discharging to give himself more time to sell the commodity, thus using the ship as a warehouse until such time as the merchandise can move directly into cars without the double handling of piling on the wharf. This is not a question of terminal facilities but of the policy of corrective or punitive rates for wharfage.

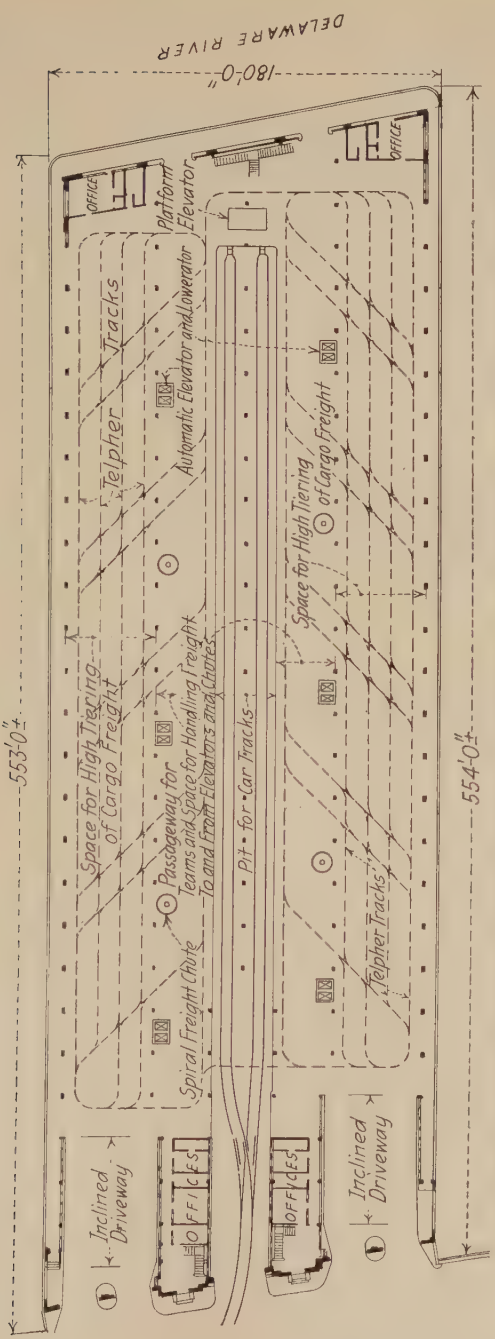


FIG. 106.—Proposed overhead Telpher tracks for a Philadelphia pier but never carried out because of excessive cost.

The Telpher or Overhead Monorail Trolley.—Another innovation to reduce the time and expenses of handling general merchandise in the transit shed and elsewhere is the telpher. The system has not fulfilled expectations because of its lack of flexibility, its cost of installation, and primarily because it has been required to do more than could reasonably be expected. However, in the case of standard packages such as sugar, cotton in special warehouses, and similar commodities of a standard size the telpher has been a decided success.

The first drawback is the cost of construction. Greene puts the cost of a simple system, including the increase in the cost of the pier shed structure to carry the load, at $50,000. In a plan never carried out for a Philadelphia pier, each side of the pier had five longitudinal tracks and five pairs of crossovers and fifty switches. The cost of the installation would have been more than $100,000 (Figs. 106).

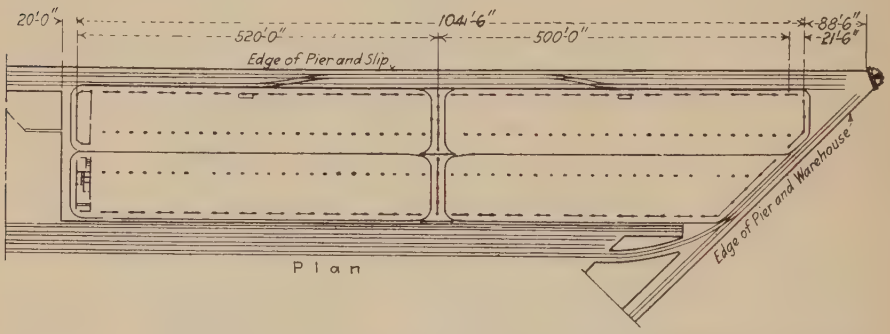


FIG. 107.—Half of double quay pier, Tacoma, showing inside and outside Telpher tracks and "adjustable loop" shop cranes.

All these tracks were made in order to have the overhead carrier reach every part of the pier deck and eliminate the hand truck. As stated above, this elimination is neither practical nor desirable. Only where there is intended to be a large movement of goods capable of tiering and requiring tiering in the transit shed is this desirable. Even in this case the portable conveyor would do the work when needed at a fraction of the invested capital. The telpher has been successful, not in the transit shed but in warehouses, such as the Chalmette Sugar Refinery and the Municipal Cotton Warehouses at New Orleans, where goods are not tiered in transit but in storage. Figs. 107 and 108.

The movable loop has simplified the telpher system for tiering. The Sprague system is the most advertised. In place of attempting to cover the entire floor area with overhead tracks and crossovers the shop crane arrangement is applied. A shop crane is a bridge spanning the width of the shop between two heavy rails, one on each wall. The bridge moves along these rails and can span any part of the shop. On the bridge is a

cage and hoisting machinery which travel the length of the bridge across the span. The movements of the bridge and the movements of the hoisting cage enable every point on the floor to be covered. The loop telpher simply takes over this system, and by making the bridge carry connecting curves and switches, the hoisting cage can leave the bridge and, traveling along the side rails to other connecting rails, pass out to the loading bridge of the wharf or to the warehouse. Where tiering is to be accomplished and not mere lateral travel, this simplified system seems capable of development. Yet, let it be again added, tiering in transit sheds is to be countenanced only when there is no room for the lateral expansion of the shed. In the warehouse, the telpher system has already demonstrated its value.

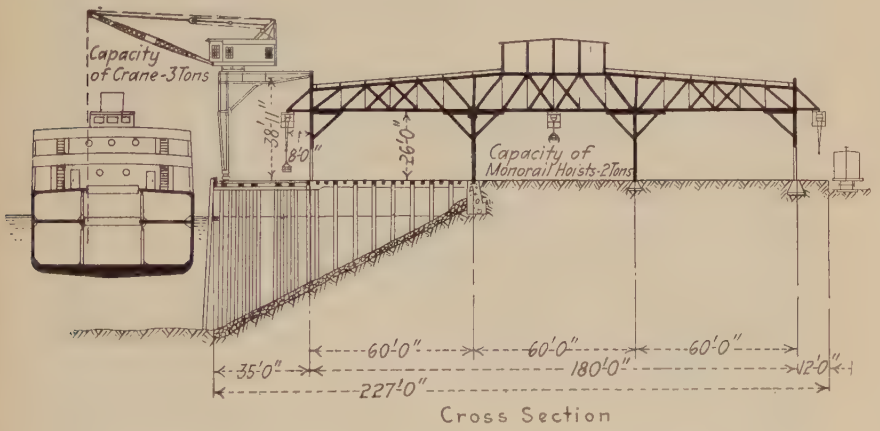


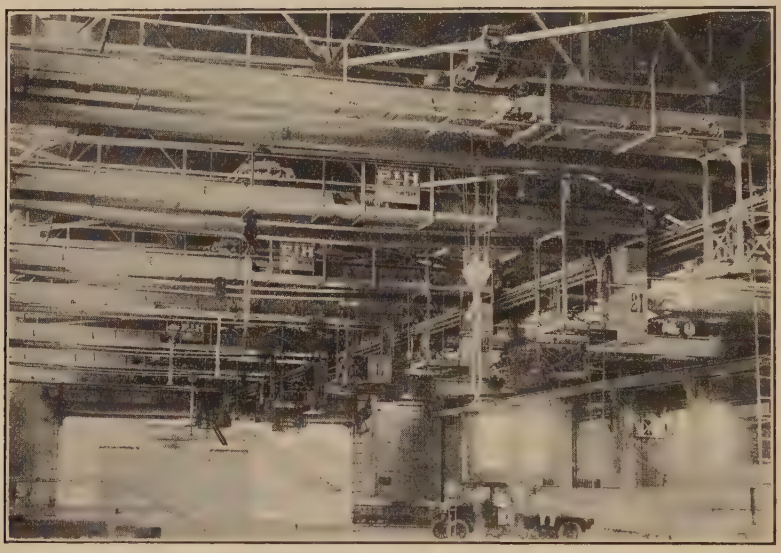
FIG. 108.—Monorail hoists (Telpher) at Tacoma, Wash.

The same principle applies to the telpher system as to the electric trucks. On a long pier, where the freight must be moved down the pier to waiting drays at the head house to meet the drays and keep them off the pier, *i.e.*, in service where there is long haul, mechanical movement is necessary. With the construction of a simple trunk line of two overhead tracks down the middle of the pier, standard hand platform trucks—low pushcarts—can be used for the short motion. The loaded hand trucks may be moved to the center of the pier under the trolley to be picked up by the man in the cage and moved rapidly through unoccupied space to the head house for delivery to the dray calling for the consignment. The application of the trunk-line telpher system to the system of removable bodies, motor trucks, and store-door delivery, as described under "Drayage," seems to be one of the most promising solutions of mechanical freight handling on piers.

The accent is put on piers. When the shed can be reached by dray from the back that is, its long side, instead of the end, the travel will

be too short to make the overhead telpher economical. The electric truck and skid system probably would still be economical in most cases. The saving accomplished by electric trucks over the old, hand method would not always pay the capital investment, in the short cross-shed movement. In the case of long, narrow piers, the problem is entirely different. The further success of these efforts to substitute machines for muscle in moving freight along piers will be followed by all with the keenest interest.

Shop Cranes for Interior Piling (Fig. 109).—An innovation in interior shed handling has been made at new Pier No. 7 at Manila, Philippine



(*Courtesy of E. Clinton Earle, Chief Engineer, Port of Manila, P. I.*)

Fig. 109.—Four rows of 2-ton shop cranes, 48 in all, are deing installed in Pier No. 7, Manila, P. I., for handling and tiering. Note absence of posts in this middle bay. Two central crane rails are suspended from roof truss.

Islands. Light, fast, shop cranes, 2- to 3-tons capacity and forty-eight in number, have been installed. This unusually fine pier, built by the Insular government at a cost of $4,500,000, is 1,400 feet long by 234 feet wide with a transit shed 1,253 feet by 160 feet. By using wide roof trusses, columns in the wide nave or middle bay are eliminated, and four longitudinal crane runways suspended from the roof trusses carry twelve shop cranes each. E. C. Earle, Chief Engineer and Vice-chairman of the Manila Harbor Board, who designed this pier, writes to the author his opinion of these shop cranes for shed handling:

This system is somewhat of a departure from the monorail hoist system, used on such terminal structures in the United States, fortunate enough to have

any mechanical overhead system installed, and was the result of my experience with the monorail system on Piers No. 3 and No. 5 at this port. In my opinion they are not comparable with the bridge crane (*i.e.*, shop crane) as regards flexibility. Our overhead interior installation operated in conjunction with our industrial trucks has proved up beyond the best I had hoped for. The inside cranes were built by the Shepard Electric Crane and Hoist Company and the outside gantry cranes by the Wellman-Seaver-Morgan Company.

CHAPTER IX

MARINE TERMINAL TRACK ARRANGEMENTS AND DRAYWAYS

RAILWAY TRACKS

Whatever the type of wharf, whether quay system or pier system, and whatever the proportional arrangement of transit shed and warehouse, of working space and storage space, of electric truck and dray, the fact still remains that the principal function of a port terminal is to facilitate the transfer of freight between the railroad carrier, on the one hand, and the water carrier on the other. The interrelation of railroad tracks with the other elements of the terminal complex is fundamental to the proper operation of the terminal.

The railroad tracks on the wharf apron will be discussed in connection with the width of the wharf apron in Chap. X. It now remains to discuss the entire track arrangement of the terminal, permitting, for the moment, the relative proportions of transit shed and warehouse to be assumed as established and to defer the discussion of the details of the latter element until later. The terminal trackage consists of the following main elements:

1. The receiving or break-up yard.
2. The departure or classification yard.
3. The car-storage tracks.
4. The car-loading tracks.
5. The leads or main running tracks that connect all of these elements.
6. The open-storage tracks for the storage of rough cargo in the open.
7. Special services such as round houses and repair shops, refrigeration or icing plant.

It is not the object of this chapter to go into detail with regard to the relative merits of various types of yards and their operation, as this is very ably set forth in the book "Freight Terminals and Trains" by Draege.[1] However, the best railway engineers seldom understand the design of water front track as illustrated by the many serious mistakes, from the operating point of view, in the track arrangements of the army supply bases constructed for the world war.

The elements of the discussion may be introduced by a scrutiny of the Bassen Terminal Yard constructed below Bordeaux by the Division of Construction and Forestry of the S. O .S.-A. E. F. under Brig.-Gen. Edgar Jadwin, Director. This yard includes all the elements (Fig. 110). It is laid out on the through traffic or circulating principle in

[1] Published by McGraw-Hill Book Company, Inc., new edition, 1925.

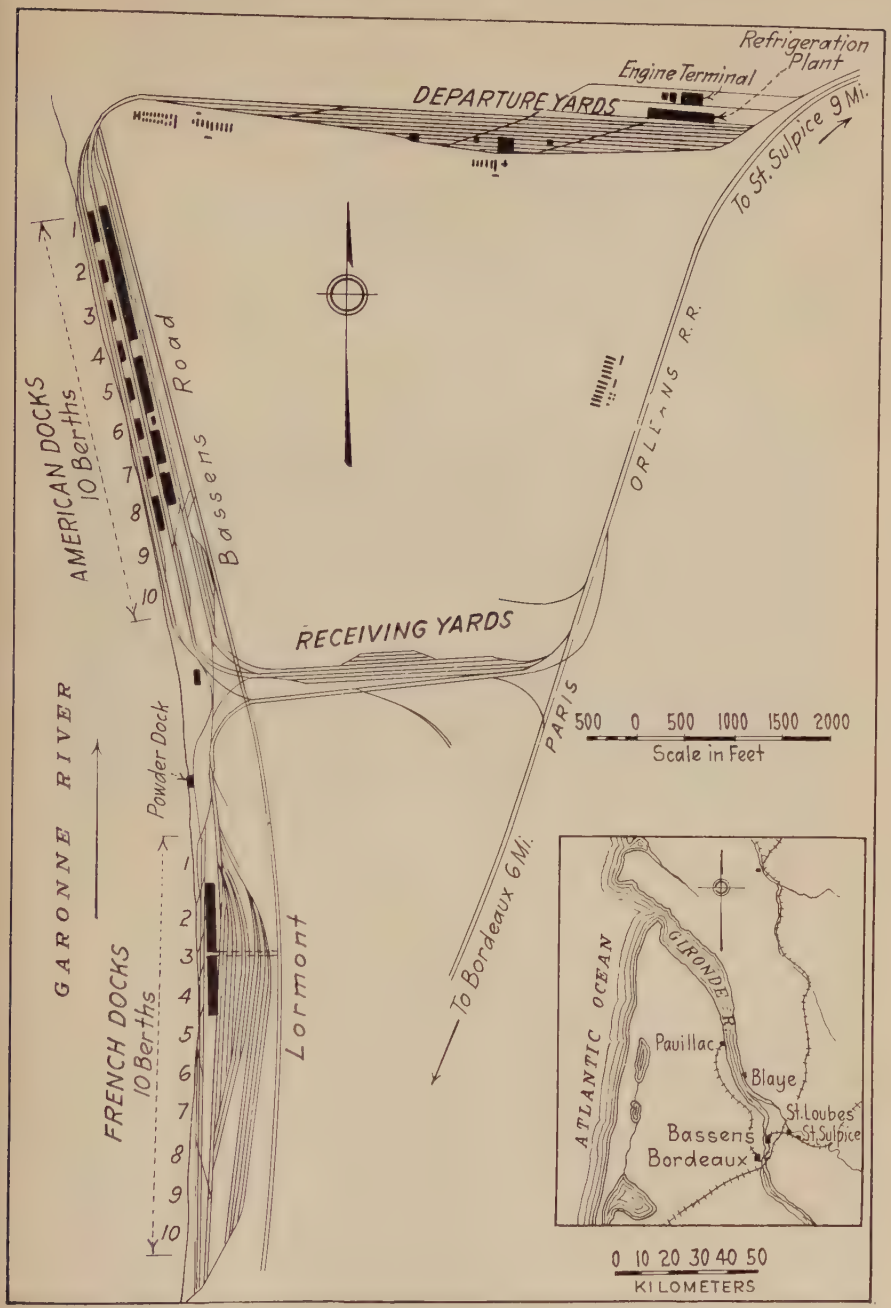
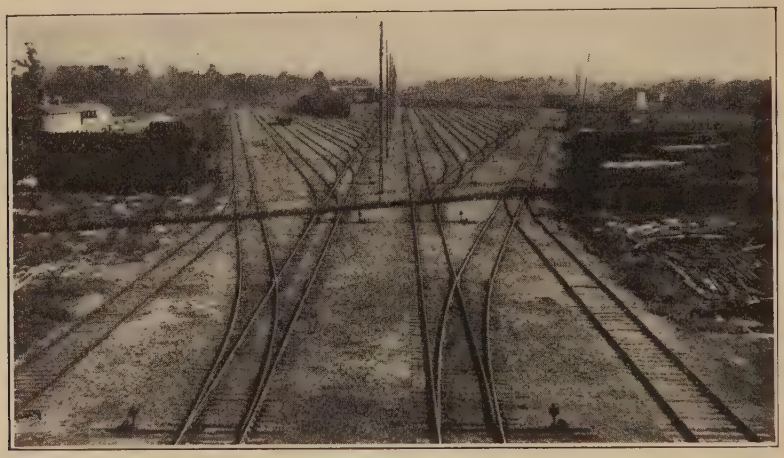


FIG. 110.—Circulating track layout. The Bassens Terminal below Bordeaux, was designed in part by Col. W. J. Wilgus, later by Col. H. C. Booz (U. S. A.), constructed by the Division of Construction and Forestry, Brig.-Gen. Edgar Jadwin, C. of E., U. S. A., Director.

contradistinction to the dead-end system that may be illustrated by the Army Supply Bases at Norfolk, Charleston, Newark, and Boston. The South Brooklyn Base is somewhat different, inasmuch as the rail freight is received largely by car-float or car ferry (see all figures showing trackage). It will be noticed that the main line of the Paris-Orleans Railroad between Bordeaux and Saint Sulpice (where was located the great storage depot) branches into a receiving yard where trains are broken up and cars switched to car-storage yards (note opposite berths 9 and 10 of the American docks, the third group of tracks) from which the cars, properly marshaled, may be set at the point in the terminal required for discharging or loading. Continuing in the same direction,



(*Photograph by the author.*)

FIG. 111.—Railroad classification and break-up yard supporting the Norfolk Army Base, located well inshore.

the cars proceed away from the waterfront back to the departure yard where the trains are made up for dispatch.

In the case of the Bassen Terminal Yard, and several other of the American Supply Bases, the classification yards are removed from the waterfront to an inland point away from the valuable deep-water frontage. It is an economic waste to occupy waterfront property with railroad receiving and departure yards as the area a few hundred feet inland from the ship's berth is extremely valuable for transfer and storage, and the area immediately behind this working waterfront is valuable for industrial sites. Therefore, railroad classification and break-up yards should be removed into the third zone of low land value (Fig. 111).

On the other hand, car-storage tracks should be close at hand to permit resetting of strings under work with the least possible delay and shortest possible switching movement. Work tracks should carry enough cars at one setting for one period of work, enabling the shifting to take

place morning, noon, and evening when longshoremen will not be kept standing idle. This is not always possible in practice; therefore, shifts should be quick, over a short distance.

The general arrangement of various types of marine terminal rail yards is illustrated sufficiently by means of the attached charts and drawings, bearing in mind several cardinal principles:

1. Tracks must be arranged to permit shifting of cars to and from each pair of hatches, or at least every berth.

2. Unless full crane equipment is installed, the ship-side track should be close to the edge to be within easy reach of ship's tackle.

3. "Sunken roads" must be avoided; preferably shed floor and apron on one level or grade with tracks set flush in the pavement.

4. Leads and siding switches should be in the same direction towards break-up and departure yards to avoid back hauling.

Railroad freight constitutes from 50 to 75 per cent of all the freight movement of most ports serving a prosperous hinterland. In the case of the quay system, the spur tracks of the harbor belt railway are located at the side of the transit shed opposite the steamer. As freight is unloaded onto the deck of the shed it is stored, or, as rapidly as cars are available for the shipment, the goods are trucked in a more or less straight line across the wharf to the cars and loaded. It is seldom very straight across, as the particular car wanted is seldom set directly opposite the particular goods to be loaded. As far as possible, however, the movement is across the shed in the shortest line.

In case of the narrow piers at New York, the same railroad freight is trucked more or less straight across the pier deck to the lighter which is the substitute for the harbor belt railroad. It would be impossible to berth cargo vessels on each side of the pier at the same time as the piers do not hold the cargo of one ship as it is. In the case either of the belt line or the lighter, the movement across the deck from unloading ship to waiting car or lighter is the shortest possible and most efficient one.

Cars Tracks on Narrow Piers.—The great controversy concerning the placing of car tracks on piers, which has aroused so much debate, is due to a confusion of very simple principles. In the first place, the idea of putting depressed car tracks down the center of a transit shed located on a narrow pier which, owing to the small width of the pier, is already of insufficient area, is out of the question. They are more in the way than serviceable. Then also, if the car tracks do not go to any place, as at New York, they serve no purpose. As long as lighters are doing the belt-line service, there is no reason for the car tracks.

Much effort has been made to befog the issue of car to ship delivery by stating that the ship cannot be loaded from the railroad car. Certain individuals and certain daily papers which should have known better harp on this perfectly true statement. No one loads all the freight from

car to ship even in the great ports of the world, where every quay is equipped with car tracks on both the water and the land side of the transit shed, except heavy pieces or certain standardized package or bulk commodities.

R. A. C. Smith in his testimony in the Lighterage Case gave some pertinent figures concerning the impracticability of loading ships directly from cars. He took a case in point at one of the Chelsea piers. There were two ships berthed at the pier, one a cargo liner of 16,000 tons (it was not stated that she had 16,000 cargo tons capacity) and the other a freighter with 8,000 tons cargo capacity. The larger ship spent the total of 5 days in port, which is rapid dispatch for such a ship at any harbor. However, it seems quite certain that the ship was primarily a passenger liner and did not discharge 16,000 tons of cargo and load an equivalent amount in 5 days.

Now, according to the Commissioner, if the ship of 16,000 tons capacity had been loaded from freight cars directly, it would have required 480 cars, or a train 19,200 feet long, 3½ miles. If the cars could be marshaled in such manner that there would be no delay in drilling in two rows of eight cars, or sixteen in all, it would take thirty shiftings to accommodate 480 cars. The best time that could be made in unloading one set of sixteen cars would be 4 hours, which he considered the utmost speed. It would take 120 hours to unload all the 480 cars. Working all the time, 24 hours of the day, it would take 5 days to load the ship. As the ship cannot load until after it has discharged, it will be seen that allowing half of the time in port for discharging at the same speed as loading it would have taken 10 days to turn the ship around. Therefore the present system would be twice as fast as car-to-ship loading.

The figures seem convincing, and were very convincing to most people, but not the least to Mr. Smith, himself. What he said is true enough. Yet when one stops to think that at other ports in the world, in particular Antwerp, Rotterdam, Hamburg, or Bremerhaven, the practice of car-side delivery is continued at all the new basins after many years' experience, and when it is known that the speed of turning a ship around is at least as great as, usually greater than, at any American port, one sees that there must be something wrong in the reasoning.

As a matter of fact, the reasoning is based on a false premise, as is the entire controversy. It is based on the premise that freight is to be transferred *directly* from car to ship. This is done in very few instances. When very heavy pieces are to be loaded the cars are spotted, marshaled, and drilled alongside the ship on tracks situated at the quay edge. Such pieces arrive on gondola cars or on flat cars. Even so, in the case of loading locomotives, boilers, engines, and other similar pieces, the quay cranes of 3 to 5 tons cannot do the work, and either the ship is moved to one of the 100 ton cranes, or, which is more usual, a derrick

lighter floats the heavy pieces alongside from some siding. We may say, therefore, that for heavy pieces, which are not too heavy for the regular cargo cranes, and when delivered in open cars, loading does take place directly from car to ship's hold. Also for bulk freight which is tipped into the hold from the car by a car hoist or "tipper," such as coal, ore, and sometimes grain, direct loading is possible. These commodities form a small percentage of general cargo and are the exception rather than the rule. Such bulk commodities are handled at special terminals constructed for the particular service.

The function of the belt railroad with ship-side spurs is not to load from car to ship, as a rule. The movement is to save rehandling to lighters or draying from railroad terminal or warehouse to the transit shed.

The loading of belt-line railroad freight is as follows, and not as described in the above testimony. The sheds are ample in area with decks not cut up by tracks or teamways. The tracks outside the sheds permit cars to be brought to both the front and back of the shed for unloading *into the shed.* This is done before the ship is ready to load. The function of the shed is to act as a temporary reservoir for the assembling of outgoing cargo so that the cargo may be quickly loaded when the ship arrives. The freight as it is unloaded from cars to the shed is placed according to the kind of freight or ports of consignment. The freight is thus assembled at ship's side from cars which have come unbroken to near the ship's side.

In the meantime the ship has been discharging at another deck or quay reserved for inbound freight. The inbound shed in like manner takes up the cargo as a reservoir pending further disposition. The further disposition is of secondary importance compared with the rapid discharging of the cargo. Once it is lightened the ship is warped across the basin to the loading quay where the freight, properly assembled, may be loaded at a speed limited only by the speed of stowing it in the hold.

It must be added that the ship-side car is only of interest when there is the inner belt line and when there is room for tracks on the quay and still room for the proper amount of deck space for working the cargo.

In addition to railroad freight there is a vast amount of freight taken overside, from barges, lighters, or heavy-duty derricks. Bunker oil and coal are loaded from the water side and also grain, except where galleries above transit sheds are provided. Both sides of the ship must be worked.

Therefore, to sum up, the car seldom loads directly to the ship, but usually to the shed for transit storage and for working. The advantage of the car-to-ship-side system is that there need be no handling of freight between the point of origin and the point of unloading at the pier shed.

The economy is in this point of the movement, and nowhere else, except certain bulky or heavy packages from open-top cars at ship side.[1]

Location of Tracks on Double-width Piers.—Where there is no belt line, the New York system of moving cargo across a narrow pier to lighters is the equivalent. When there is a belt line and car tracks are run onto the piers, the question arises as to where to put the tracks. If the tracks are run down the center, the piers at once must be twice as wide because the tracks divide the pier sheds into two separate narrow sheds in which the freight for the railroads is moved across the deck to waiting cars instead of to waiting lighters.

(*Photograph by the author.*)

FIG. 112.—Three tracks (depressed) on center line of a double pier, Army Base, Norfolk.

(*Photograph by the author.*)

FIG. 113.—Three stub tracks (each 1,600 feet long) between warehouses, Army Base, Norfolk.

Recent American pier design has taken this fact into consideration. Notably at Philadelphia, where the railroad freight is 75 per cent of the

[1] In segregating large movements of leaf tobacco in hogsheads a wide wharf apron permits unloading from shipside cars to apron and transfer, with a minimum of rehandling.

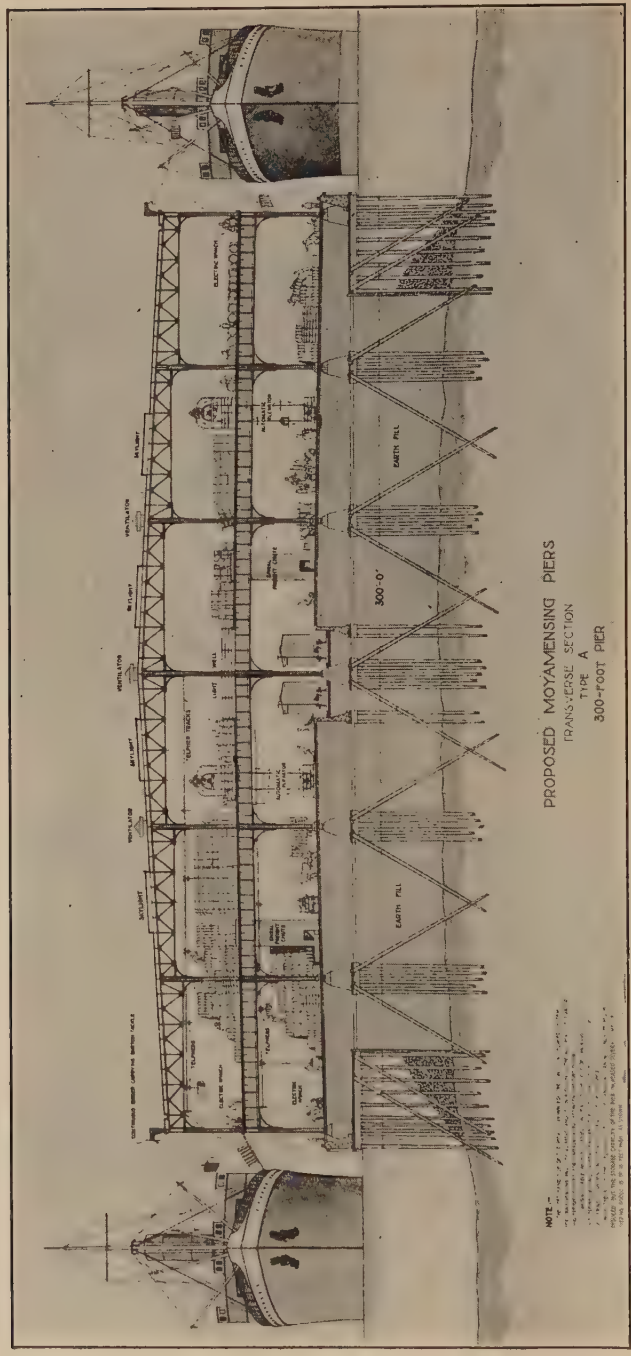
whole, the tracks have been laid down the middle of the pier and the pier made wide enough to leave two separate shed floors, one on either side. Although they are on one pier and under one roof, in fact there are two sheds as far as working cargo is concerned.

In the drawings (Fig. 114) of the new Moyamensing Piers, the cross-section of Type A shows a total width of 300 feet with the car tracks down the center and two roomy transit-shed floors, one on each side of the track. This system has been used for some time in other smaller and older municipal piers. Figure 115 shows Type B with a driveway for teams down the center and the car tracks moved to the outside edge of the pier. The movement would be by tackle hoists over the car tracks to the shed and then into the cars to be shipped by rail from the shed. The driveway for teams has completely divided the pier into two separate units. When the first of the Moyamensing group was built, in the spring of 1918, it was given the floor plan of Type B, but on investigation it was found as economical to roof over the entire pier including both pier sheds and carry the upper deck through, as to build the sides of the two sheds. This arrangement gave the teams covering while loading and at the same time added the space of the driveway to the second deck of the pier. Figure 116 shows the McKean Street Pier, No. 78, Philadelphia, with its car tracks on the upper deck in the center and on the lower deck with the tracks outside and with the teams in the middle.

TRACKS AND CAR-LOADING PLATFORMS

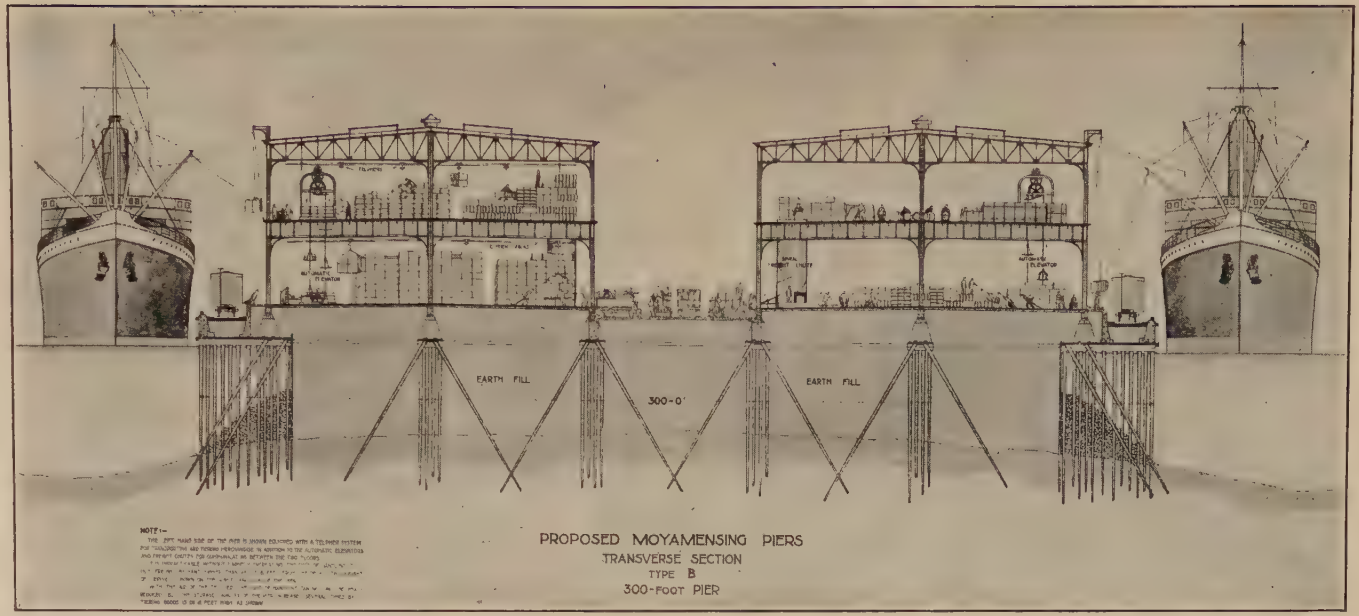
Quay-type Layout.—The arrangement of tracks on the wharf apron, that is, the space between the ship's berth and the transit shed, will be discussed in Chap. X. The next element is the relation of the arrangement of tracks with reference to the car-loading platform of the transit shed, considering first the quay system of layout as at the Bassen Terminal and other examples.

Loading Platforms.—A loading platform should be roomy, 6 to 12 feet wide, with an overhanging marquise roof for protection, but without obstructions such as posts or other supporting columns at the edge of the platform next to the tracks. This platform is 40 inches above the tracks in order to afford an approximate car-floor level. Box cars are not of uniform height, but 40 inches is assumed as a workable average. Box cars are spotted opposite the points at which loading is to take place in order to avoid frequent shifting, which means that the entire loading crew in the transit shed or warehouse must remain idle during the shifting process. The cars are usually spotted on two and sometimes three tracks with their doors opposite so that the far car may be loaded by trucking through the car or cars next to the platform (Fig. 100). These cars are usually spotted before the working day begins on the wharf, and are usually pulled at noon and at the close of the working day. To



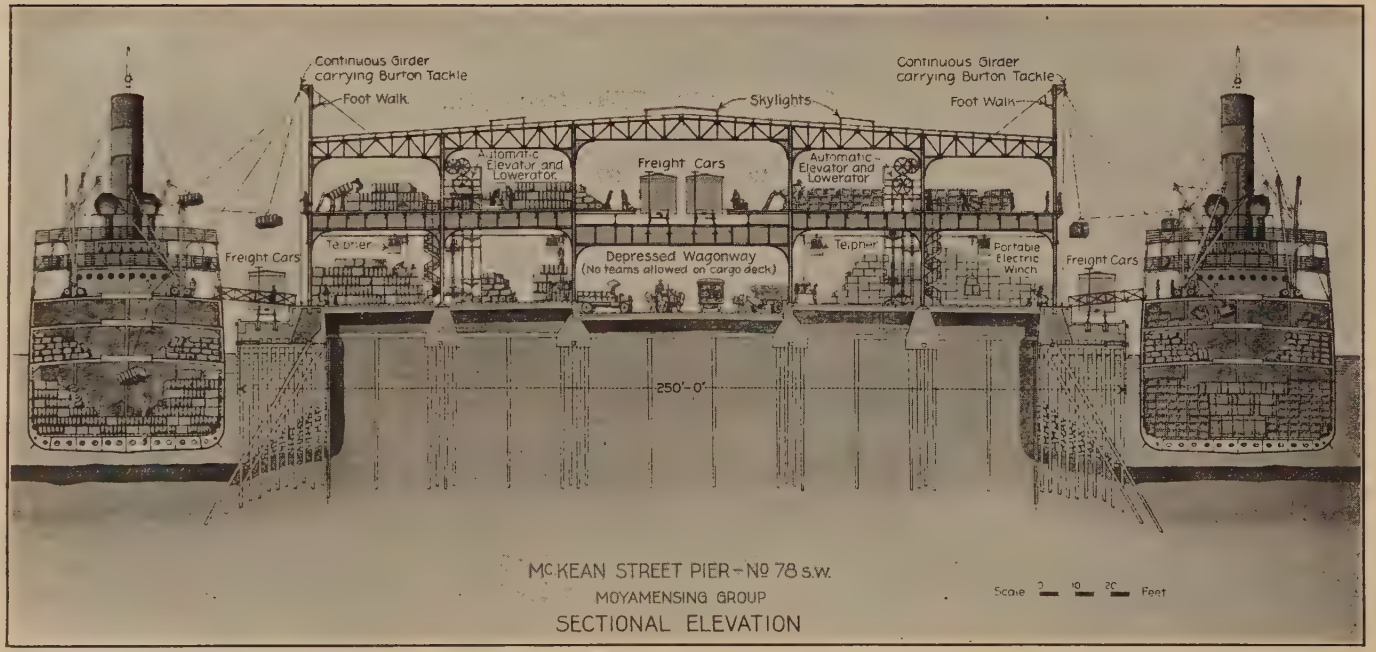
(*Courtesy of Dept. of Wharves, Docks and Ferries, Philadelphia, Pa.*)

FIG. 114.—Proposed Moyamensing Piers, Type A.



(*Courtesy of Dept. of Wharves, Docks, and Ferries, Philadelphia, Pa.*)

FIG. 115.—Proposed Moyamensing Piers, Type B (not executed).



(Courtesy of Dept. of Wharves, Docks, and Ferries, Philadelphia, Pa.)

FIG. 116.—McKean Street Pier. No. 78 S. W.

accommodate a sufficient number of cars, two or three loading tracks are necessary on the inside edge of the car-loading platform.

If the sheds are long, the sidings must be provided with frequent crossovers to the lead track to permit of cars being drawn at frequent intervals. This is in order that loaded cars may be moved without disturbing other cars in which work is progressing. The situation is similar to that of the wharf apron to be discussed. There is, however, more room available inshore than on the apron in which to develop other types of track arrangement.

Saw-tooth, Car-loading Platforms. Savannah Variety.—The crossover tracks require a break in the loading tracks of 60 to 75 feet. An effort to solve this difficulty by means of a saw-tooth loading platform is shown in the very excellent terminal of the Ocean Steamship Company at Savannah, Georgia, on the left-hand freight shed (Fig. 117) for inbound traffic being loaded from vessels. As outbound freight is for one destination, New York, segregation of cars is not necessary. There are five arrival tracks on the wharf, one singleton and two pairs, with the southbound freight shed on the left-hand side facing the river. The single track with platform serves the city delivery shed for teams. By "southbound" is meant rail freight coming south out of Georgia, not ship movements. In this case, the entire string of cars on each track, approximately 1,000 feet in length, must be marshaled and set and pulled again as a complete string, there being no crossovers available. The same situation is found at Norfolk Army Base, both piers and warehouses, and the warehouses at Newark and Charleston Army Bases.

In the case of the southbound, or outbound, and local Savannah freight, the continuous-platform arrangement is satisfactory because there is less segregation than in the dispatch of freight inbound from vessels to many interior destinations or transfer points. To afford greater freedom in moving a few cars without interfering with the great number being loaded, the inbound freight shed (left), that is the receiving shed from the ships, is constructed on a modification of the principle of the saw-tooth loading platform. There are five pairs of dead-end tracks branching from a lead penetrating the freight-shed floor at an angle, with platforms between. This makes it possible to load any car through its own door direct and to pull any string of three or four cars as desired. This is a modification of the principle of the saw-tooth loading platform for truck deliveries by means of which motor trucks with removable bodies park at an angle of 45 degrees against a tail-board platform set at 45 degrees to the longitudinal dimension of the delivery shed.

The saw-tooth arrangement for car-loading has been attempted for each individual car (one car = 42 feet + switch; about 70 feet). An angle and length of spur is chosen to accommodate each box car with its door clearing the end of the car on the track before it. This arrange-

ment gave a maximum flexibility of car dispatch. For instance, a terminal might have ten to fifteen of these short, stub tracks, each holding a

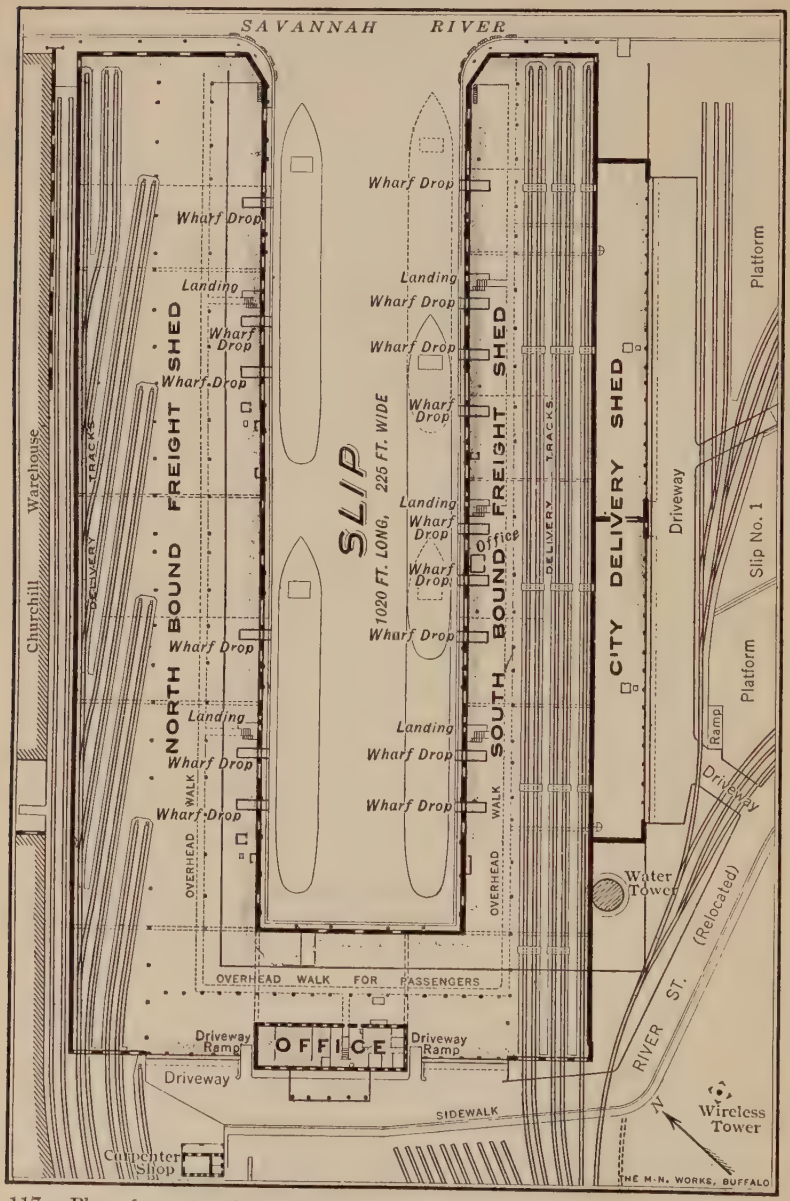


FIG. 117.—Plan of new terminal at Savannah, Central of Georgia Railroad, showing saw-tooth platform at left.

package freight or l. c. l. car for a different destination or for a rerouting point in the interior. In this case, each car, labeled with its destination,

would receive package freight throughout the day and be pulled to the departure yard and classified, or made up according to destination. The difficulty was found in the expense of the many switches, platform edges, and other elements of construction, and also in the cost of switching each individual car into its pocket. The Central of Georgia Railroad at their Ocean Steamship Company wharves have overcome many of the objections by developing the saw-tooth principle on a larger scale that permits the siding of several cars on each string for package or full-car loading.

The Saw-tooth, Car-loading Platforms. Houston Variety.—Further modification of the principle of the spur-loading tracks set at an angle from

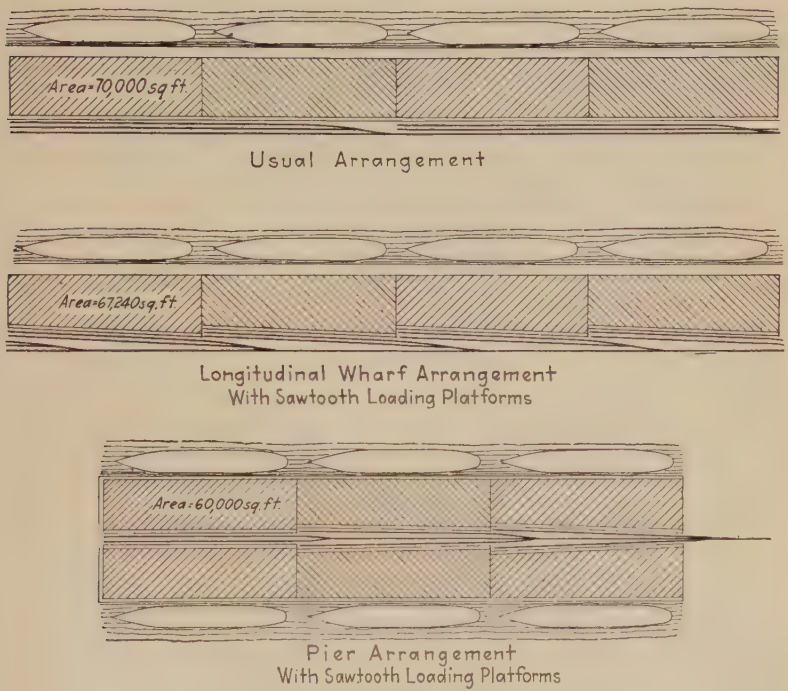


FIG. 118.—The Allin-Houston type of sawtooth shed.

the lead and with the transit shed has been developed by Major B. C. Allin at Houston. Major Allin has applied the same principle as that of the Central of Georgia Railroad but on a larger scale, less expensive of construction and less prodigal of space. In this case, two spurs branch from the main lead for the full length of each transit shed. If the transit shed accommodates the cargo of one ship, the cars in the rear of the 500-foot shed would amount to three strings of twelve cars each or thirty-six cars, any string being in a position to be moved and another set in its place at any time. This is a more economical cost of construction than

the saw-tooth platform and also saves the waterfront space required by the switches from the lead to the siding, inasmuch as the saw-tooth principle permits the switch to the next transit shed to overlap. This is easily visualized from the drawings (Fig. 118). The saving is 194 feet for each three-siding crossover on the waterfront—70 feet for one-track crossover, 132 feet for two tracks, 194 feet for three tracks. A set of thirty-six cars should represent 720 short tons with 20 tons average carload. Shifted at noon would represent a day's work of 72 cars, or 1,440 tons of railroad freight, besides local deliveries by dray and transit shed storage.

Objection is raised to the irregular shape of the transit shed. The transit shed, however, is constructed as a rectangle, the irregular or pie-shaped portion between the tracks and parallel wall of the shed being added to the rectangular shed by means of a light "lean-to" structure. It is recognized that a rectangular transit shed or warehouse is more economical because all of the roof trusses and column spacings are alike and fabricated material may be used in construction. The only deviation is for the additional loading platform space.

The question of track layouts for warehouses is essentially similar to that of the transit shed and requires no further explanation. The application of these principles will be seen in the drawings under the chapter on "Warehouses."

The area between transit shed and warehouse occupied by tracks should be constructed of channel rails set flush with the concrete pavement to permit a free movement of tractors, trailers, and delivery trucks. The 40-inch loading platform should be broken from time to time by a ramp that would permit free movement of tractors and trailers across this space and between transit sheds and warehouses. If practicable, the best location for such ramps would be the crossover points of the switches as cars would not be spotted at those points.

The Dead-end Track Arrangement.—The Bassen Terminal track arrangement was designated as a circulating or through-track layout in which the movement is in one direction into and out of the terminal in a circulating stream. Terminal layouts with a head house and wings require dead-end spur tracks that branch from the leads at a more or less sharp curve (short radius). This system requires both more space and more locomotive operating power as well as delays and derailments. Dead-end tracks also require the more frequent occupation of the lead track as the dead-end spur tracks necessitate the string of cars being hauled back over the lead before proceeding to the classification, departure, or car-storage yards. In case dead-end tracks are installed of more than 500 or 600 feet, they should be three in number with frequent crossovers, the middle track being used for shifting cars. This rule as to crossovers was not followed at the Army Bases, Charleston, Newark, and Norfolk (Fig. 113).

The dead-end track in serving a ship's berth at right angles to the waterfront is subject to more rapidly increasing trucking distance. The preference would be for the circulating layout of tracks, sheds, and warehouses.

Track Arrangements with Regard to Refrigeration.—For the purpose of handling chilled or frozen perishables, such as fruit, vegetables, and meat products, between ship and refrigerator car, the question of trucking distance and of track layout is one of great importance. At London, the cars are set in the rear of the transit shed parallel with the ship's berth, and a short trucking distance from the hatches. In New Orleans, in handling bananas, the tracks are short spurs and set at right angles to the ship's berth, but extended through the transit shed to the wharf apron. The fruit then moves by conveyors at right angles to the ship and parallel with the car tracks, at which points it is inspected, classified, and loaded into refrigerator cars. Also in this case, the movement is a short one, the average being somewhat better than at London. The equipment of a wharf for the transfer of refrigerated products should include a pre-cooling house in the car yards in which the cars would be chilled and supplied with ice and then promptly drilled into the loading shed. The transit shed itself should be chilled in the case of handling meat products particularly. All doorways should be covered with heavy canvas flaps or doors equipped with automatic closing devices. In addition, there should be a canvas-covered runway across the wharf apron to ship side to protect the merchandise from the sun or from warm air. The principle of the short trucking distance between the point of deposit and the freight-car door is raised to its highest potential in this type of merchandise.

In all refrigerated traffic the tracks and cars should enter the shed, which should be refrigerated.

The Open-storage Tracks.—Terminals in which heavy materials are handled, such as the great shipment of railroad equipment through the Army Supply Base at Norfolk during the war, require open-storage space, set aside on high, dry ground with track sidings. The same principle applies in the case of car-delivery yards for local freight in ordinary railroad terminals. There is a ladder track with spurs set in pairs with an intervening storage area between the pairs of tracks. In the case of heavy materials at the Norfolk Base, there were installed locomotive cranes of various types also fitted with magnet lifts. The crane would operate on one track handling the heavy materials to the storage area from gondola or flat cars on the parallel track.

Elevated Belt-railway Spurs.—Because of the high cost of construction in elevating tracks, it has not been the usual practice to provide the second story of transit sheds with rail tracks for car-loading. The principal cost is not alone the much heavier structure necessary to carry

the cars, but the long approaches necessary to elevate the tracks to the second floor.

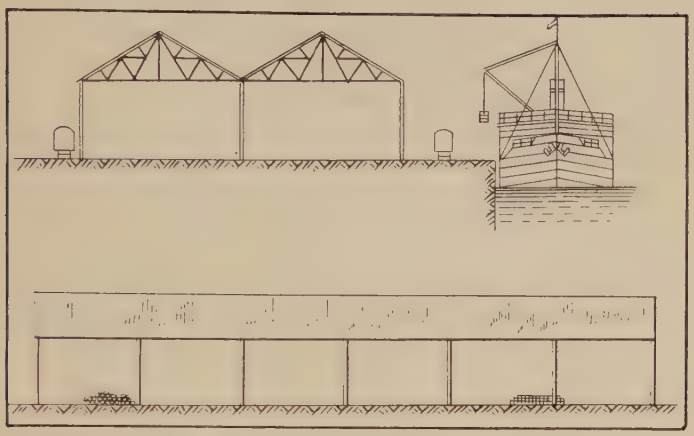
Various plans for the introduction of rails to the west side of Manhattan Island, namely, the early designs of the late Calvin Tomkins and later ones in connection with the plans for the freight railroad and motor-traffic bridge across the Hudson River by Francis Lee Stuart, all emphasize the necessity of elevating the entire belt line serving the waterfront in order to give rail service to the piers and at the same time permit access to the piers by trucks for local delivery. In this case, the entire belt-line system being elevated for other considerations, it would be a simple matter to provide spur tracks on the second-floor piers. The additional cost can be charged to the relief of city street congestion and not to the terminal itself. Terminal operations should not be required to earn interest on a purely municipal benefit. Also the warehouses on the inshore side of the marginal street would have the car-loading and receiving tracks on the second floor, leaving the ground floor open to trucks. This solution, although very expensive, has great merit. Expense in all terminal design is merely relative if the volume of traffic is sufficient, as it is in New York, and the value of property is great because of its earning power. The capital investment in elevating the entire belt line and providing car-loading platforms on the second deck of pier and warehouse would not be out of proportion to the benefits to be gained and the volume of traffic that would move over the installation.

Rail Approaches from High Shores.—In the case of port facilities at harbors with high shores, it is frequently more economical to build the rail sidings on the second or third floor than to make the cuts necessary to reach the lower level of the wharf structures at an economical grade. This is the case at Halifax, in which the three-story building for passengers, of quay design, has the tracks on the second floor, leaving the main deck (quay level) largely for trucking. Wherever the terrain is of such a nature as to permit the arrangement of the railroad tracks on the second deck of the pier, this arrangement is advantageous, as it removes all the troublesome and dangerous switching tracks from the street level, much to the benefit of cart men and the public in general.

Discussion of Three British Track and Shed Arrangements.—By analyzing additional examples (Figs. 119, 120, and 121) of track arrangements, various points for consideration may be more clearly developed. Three such examples come ready to hand from a British writer.[1] In these examples, differences of commodity seem to be unduly emphasized, as it would seem to us that all these examples of fish, fruit, and butter would fall under general cargo equipment, subhead perishables, unless special machinery could be used exclusively for certain of these products

[1] Baldwin, Christopher E., "The Layout and Equipment of Quay-side Transit Sheds," *The Dock and Harbour Authority*, March, 1925.

as in the case of bananas or frozen meat, thus putting them in the group of special uniform commodities. Therefore, these three examples have no special reason for being considered apart from general cargo wharves handling perishables.



(*From Dock and Harbour Authority, March*, 1925.)

FIG. 119.—Transit shed for fruit, butter, etc.

The first example (Fig. 119) has four tracks at floor level on the wharf apron and only one on the land side of the shed. The quay is not equipped with transfer machinery. As discussed above, it would seem

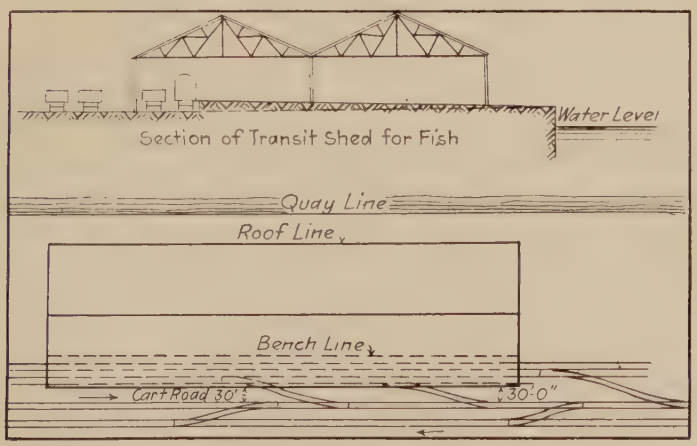


FIG. 120.—Transit shed for fish.

that two tracks at floor level for open-top car-loading would be all that could be used on the wharf and two depressed tracks in the rear. As this traffic is to be largely perishable freight, the shed should be moved as close as possible to the ship side, with due allowance for two ship-side

"emergency" tracks; emergency, because chilled or refrigerator cars would not frequently load direct from the ship when a chilled shed is provided, as the process is too slow. Also there must be inspection in addition to sorting as to marks. The wharf apron should be wide enough to permit eventual installation of the banana-unloader type of equipment.

The single track at the rear of the shed is at the shed-floor level. It should here be a double track with the shed floor at the car-floor level. As the traffic is to be largely made up of perishables, the tracks inside the shed, as in Fig. 120, would be of great advantage. This would permit easy regulation of temperature, cooler in summer and heated in winter, to prevent freezing, when and where necessary. It would permit complete refrigeration of the entire compartment.

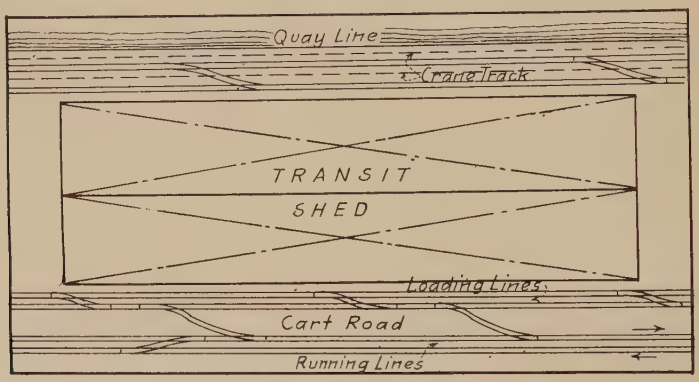


FIG. 121.—General arrangement of lines.

The Fish Quay (Fig. 120) has no quay-side cranes nor rails. The fish trade requires space to spread out, clean, inspect, pack, re-ice, store, and transship. It is necessary to bring the catches direct to the shed for these processes. But the grade of the floor of about 3 per cent from quay-side to car-floor level may be troublesome to the hand truckers when the floors are wet, icy, or slippery. On the other hand, this grade makes frequent flushing down with a fire hose quicker and easier. It would, however, be our method to have the tracks depressed, *i.e.*, the transit shed and quay level 40 inches higher than shore-side tracks and drayway, and grade each bay of the shed to a separate drain. The grades would be less and each unit would be washed down independently without disturbing work going on in other bays and sections. (A section is the quadrilateral between four posts.)

A well-balanced layout of all elements is shown in Fig. 121. There is little that can be improved on in this plan. The crane could well be of the half-arch type for economy of wharf. The straight-line, double-crane feature of the Hamburg type could be added and the water-side crane rail could be closer to the edge of the wharf. These two changes

would bring the two rows of cars into the 13-foot center relationship, and also somewhat closer to the ship side, thus condensing the dead space to a minimum and increasing the variety of operations possible on the wharf apron. The other suggestion is the inclusion of the inshore loading tracks within the shed, so useful in loading and unloading operations of all kinds of perishable and damageable cargo in bad weather, rain, cold, or heat.

In present wharf construction, electric locomotives, or at least electric capstans, are coming to be standard practice, making tracks inside sheds practicable by reduced fire hazard and smoke nuisance. Layout (Fig. 121) is exceedingly well balanced.

Transit-shed Tracks and Trucking Distances.—An analysis of the distances that freight must be trucked between the point of deposit at ship side and each car door of a string of box cars yields a most interesting and illuminating relationship, from which may be deducted the theorem that *wharf tracks parallel with ship and shed average half the hand-trucking distance between sling and car door as for tracks at right angles with the ship* (Table V).

The Army Bases are taken as examples. Although not absolutely accurate, the distances from a selected hatch to each car door of a string of twelve were carefully scaled off on the plans, and the figures obtained for the tables are accurate to within only 2 or 3 feet. It is assumed that two strings of twelve cars each are set with doors registering. The distance from the car door of string one to a car in string two is a constant; likewise distance within the car. These distances are ignored in the table. The point of deposit is taken as the wharf edge, while in fact it is 4 to 8 feet inside this line, but that is also a constant in relation with all the measurements. Each draft may vary a few feet in the day's work. In addition, the assumption that a motor- or hand-truck load will move in a straight line to each car door is inaccurate, because it must find its course through aisles between cargo piles on the wharf. The Charleston and Newark examples would naturally have straighter trucking lines, but even here the movement parallel with the ship before reaching the axis of the loading platforms will about offset the deviations of course to reach the car doors in the other examples. The object is to arrive at relative advantages or disadvantages of two systems of track layout. In one important particular, the figures underestimate the situation by giving only one round trip per car when many trips are necessary to fill a car. The number varies according to the nature of the freight and the tonnage loaded into each car. The total trips are variable but one single trip per car for each car is comparable.

Wharf-apron tracks are always only emergency tracks and do not enter the question under discussion. It may be noted again that these car tracks under discussion are transit-shed, not warehouse tracks. At

TABLE V.—TRUCKING FROM SHIP'S SLING TO CARS BY DIRECT LINE (WHARF APRON TRACKS NOT UNDER CONSIDERATION). ASSUME TWO 12-CAR STRINGS (504 FEET) SPOTTED PARALLEL WITH DOORS OPPOSITE = 24 CARS (42 FEET), DOORS ON CENTER

Location of terminal	Cars						Cars						Total all twelve car doors one trip each and one way only.	Average trip one way.	Average round trip.
	1, feet	2, feet	3, feet	4, feet	5, feet	6, feet	7, feet	8, feet	9, feet	10, feet	11, feet	12, feet			
Boston Army Base. Trips begin to cars 6 and 7 and fan out. Track in rear of transit shed, 36 + 100 = 136 feet.	288	251	212	180	152	135	135	152	180	212	251	288	2,436	203	406
Brooklyn Army Base. Trips begin to cars 6 and 7 and fan out. Tracks in center of pier.	250	210	175	135	95	65	65	95	135	175	210	250	1,860	155	210
Charleston Army Supply Base. Trips begin car 1, distance to first car wharf 40, shed 150 feet, platform 20, ½ car 20 =	230	272	314	356	398	440	482	524	566	608	650	692	5,632	470	940
Newark Army Supply Base Trips begin car 1, straight line to first car 90 + 20 feet to door = 110 feet, but most hauls longer as hatch not opposite tracks.	110	152	194	236	278	320	362	404	446	488	530	572	4,092	361	722
New Orleans Army Supply Base. Trips begin cars 6 and 7 opposite hatch across wharf, 20 + 170 feet.	318	285	255	228	205	181	181	205	228	255	285	318	2,944	245	490
Norfolk. Trips begin cars 6 and 7 opposite hatch. Wharf 36 feet + deck 94 = 130 feet nearest car track.	286	249	210	178	150	133	133	150	178	210	249	286	2,410	202	404
Philadelphia. Army Base, almost exactly the same dimensions as Norfolk.															

Charleston and Newark the same tracks serve both transit sheds and warehouses. In the case of Norfolk or Brooklyn, the pier tracks are down the center of the pier, but at Boston and New Orleans, they are in the rear of the transit shed of the marginal wharf. There is no essential difference in these four examples as the question is on the distance from sling to car, not from shed to car, or to warehouse or through the warehouse to car. As from 50 to 80 per cent of a port's tonnage in general (except perhaps at New York), cargo moves this way this is a most important question.

The answer to the question given by the figures in Table V is emphatically in favor of rail tracks parallel with the ship and transit shed, not at right angles with it. The examples of Boston and Norfolk with approximately 100-foot-wide shed floors and 36-foot aprons show almost the same average trucking distances, *i.e.*, 203 and 202 feet. The greatest variation of the trucking distances at these two bases is only 153 to 288 feet. The advantage in operation is with the Boston Base, which is a quay type compared with Norfolk's double piers because Boston can spot two strings or twenty-four cars at all times while the Norfolk pier when working both sides can give only one string of twelve cars to a berth, the middle track being a running track. If one side of the pier only is in use, three strings can be spotted, but that is not the intention of the pier design. This limitation to working both sides applies in greater measure to the two tracks on the Brooklyn piers. The apparently more advantageous arrangement as shown by the low trucking average of 155 feet at the Brooklyn piers is made at the sacrifice of deck space for working cargo and of car capacity necessitating more frequent settings. It is highly desirable that enough cars per berth be set at one time to enable continuous working throughout a shift of longshoremen, the strings being pulled and reset during lunch hour and during change of labor shifts if working overtime. Any reduction in available car capacity to the point where strings must be pulled on labor working time, with the men standing around and drawing pay waiting for cars, is an operating loss that will offset many times the saving in the reduction of trucking distance by a few feet. Likewise, narrowing the transit-shed deck to a point where it becomes crowded in operation, the aisles narrowed, and trucking speed reduced or damages increased, is poor economy. In the Brooklyn example, the difference between greatest and least trucking is 145 feet or only 10 feet less than at the more commodious Boston layout. Very little is gained and much may be lost under high-pressure work at Brooklyn sheds compared with the Boston shed. The quay layout is here again superior to pier layout.

The right-angle stub tracks at the Charleston and Newark bases show long distances. Charleston's nearest car is 230 feet, only 50 feet less than Boston's farthest, while car No. 12 is nearly 700 feet from the ship, a

round trip of 1,400 feet or over a quarter of a mile. A right-angle stub track at best will increase the distance of the car doors twice as fast as a parallel track, and by a full car length each time, and "drags at each remove a lengthening chain" of costs.

Each additional car added to a string set parallel would result in a formula:

$\sqrt{W^2 + (N \times 42^2)^2}$

W = width of apron and shed.

N = number of cars not exceeding six from center in each direction. In right-angle tracks, each succeeding car for all twelve cars is 42 feet farther, by simple addition.

In reconditioning the Charleston Base, effort has been made to extend some of the sets of tracks through the head-house transit shed to the bulkhead, 40 feet from the water. This will bring the first car the width of the rear platform, 20 feet, and the width of the transit shed, 150 feet, or a total of 170 feet nearer to ship side. This is a great improvement for the first few cars but each car is still 42 feet farther than the one in front. In a parallel track layout, the increase is much less for each succeeding car door and for only half the distance as the measurement moves right and left for half the total length in each direction.

In this reconditioning at the Charleston Base, it was suggested that the initial error might be remedied by cutting a right-of-way parallel with the transit shed through all the six warehouses, and installing hand-operated bascule bridges to cross the depressed tracks to reach the warehouses. This would have resulted in parallel transit-shed tracks, stub-end ware house tracks, a good arrangement, but with less direct connection between ship and warehouse. The cost of cutting a three-track right-of-way through fire walls, cement, fire bricks, under pinning the tracks with piles, installing of crossovers, loading platforms, etc., was prohibitive. Redesigning a finished terminal is expensive, like remodeling an old house.

Hand-operated Bascule Bridges over Sunken-tracks.—The problem of the proposed sunken tracks separating the transit shed from the warehouses was to be solved by hand-operated bascule bridges. Forty-inch lower level tracks are a complete barrier in intraterminal trucking without bridges across the ditches. In large transfer freight houses where l. c. l. freight is rerouted and transferred from one car to another, the series of parallel platforms between pairs of tracks are connected by such bridges. Each set of cars must be uncoupled and spotted to give breaks across which the bridge can be lowered. Again when the cars are to be pulled, the bridges must be lifted and the cars recoupled into trains. However, this is not so complicated and does not take very much time. It is one of the prices paid for one-story construction. In the Boston Base, etc., fixed bridges cross the tracks at second-story level. Such crossover bridges are better traveling on crane rails.

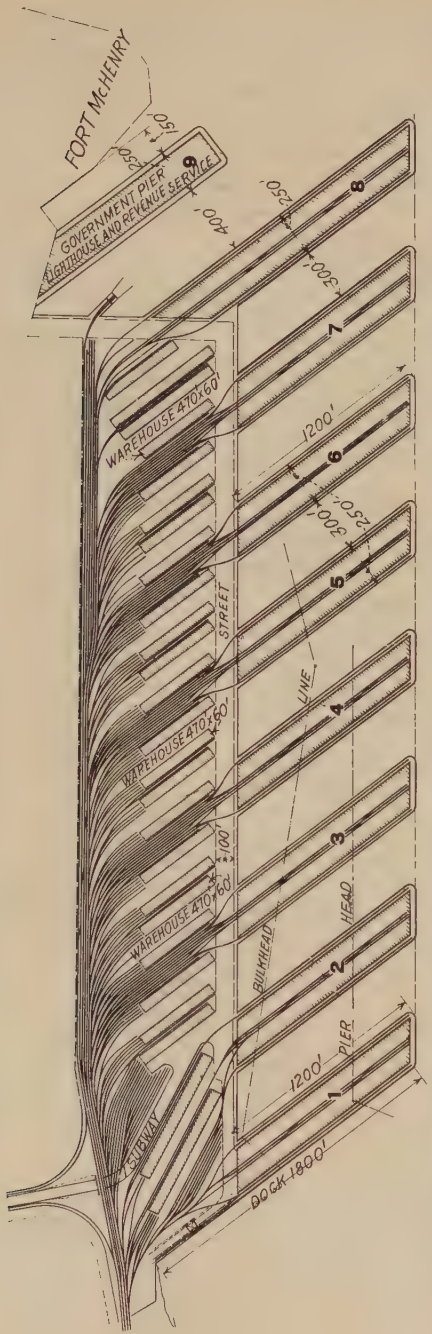


FIG. 122.—Proposed McComas Terminal, Baltimore. Stub track arrangements for double piers and warehouses. Layout at a deviation from the perpendicular gives large turning radius for tracks and for ships. Subway affords dray access to marginal street.

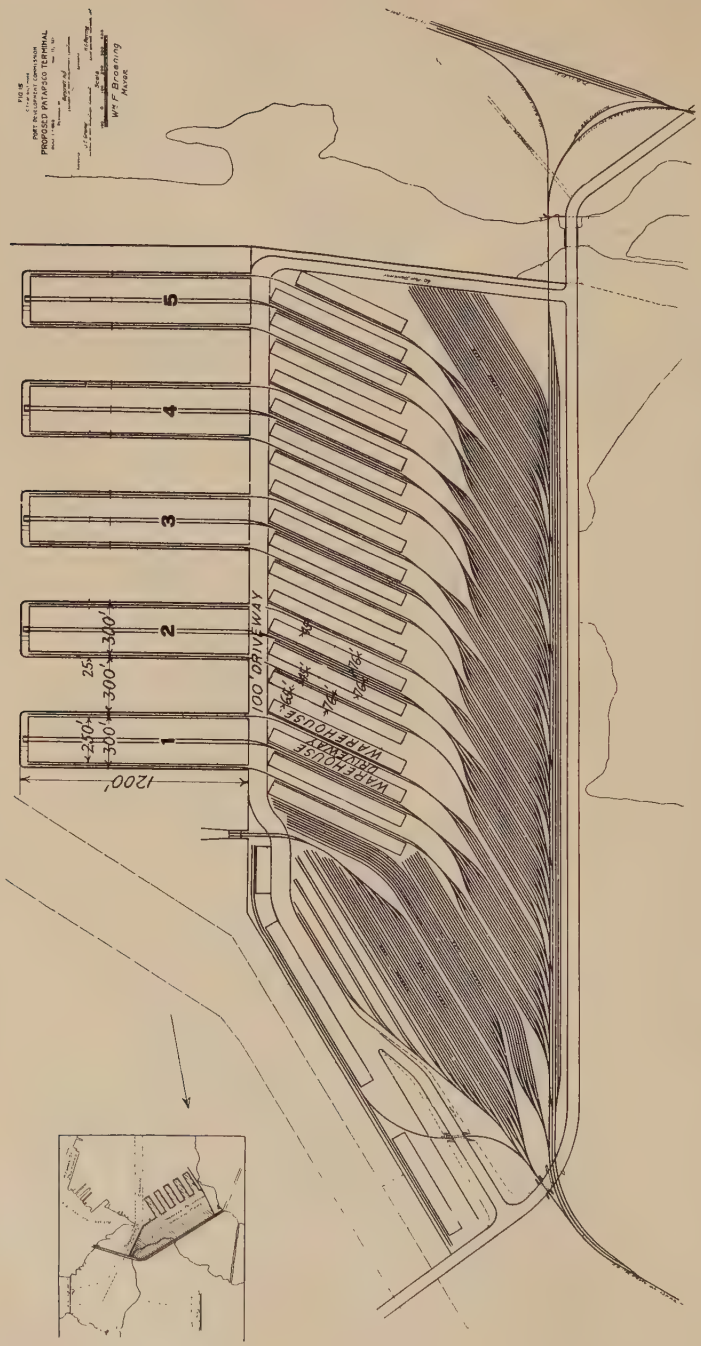


FIG. 123.—Stub track system at proposed Patapsco Terminal, Baltimore.

Also the transit-shed tracks may be brought inside the shed and parallel with the ship's berth, by providing bascule lift bridges across to dray-loading platforms; also ramps may be added at intervals to enable trucking across marginal street to warehouses. Or a telpher may be used to cross through unoccupied space. We have no example of such a layout to offer embodying all of these suggestions although various elements exist in independent examples. Someone somewhere may have

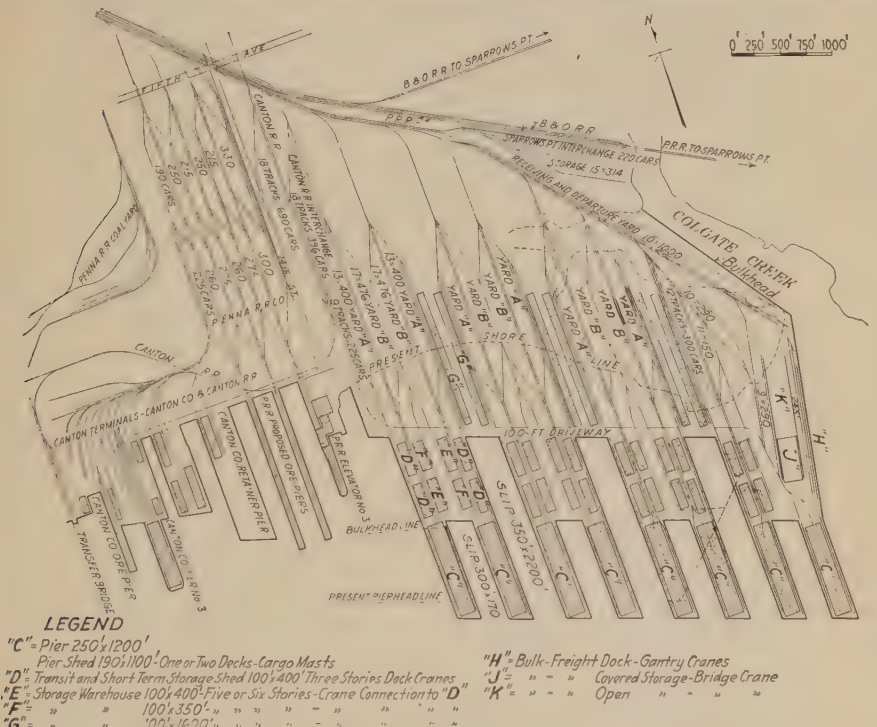

B&O R.R. TO SPARROWS PT.
P.R.R. TO SPARROWS PT.
COLGATE CREEK Bulkhead
CANTON R.R.
CANTON TERMINALS - CANTON CO. & CANTON R.R.
CANTON CO. PROPOSED ORE PIER
PROPOSED ORE PIERS
TRANSFER BRIDGE
BULKHEAD LINE
PRESENT PIERHEAD LINE
100-FT. DRIVEWAY
SLIP 350'x2200'
SLIP 300'x1700'
LEGEND
"C" = Pier 250'x1200'
Pier Shed 190'x1100'-One or Two Decks-Cargo Masts
"D" = Transit and Short Term Storage Shed 100'x400'-Three Stories-Dock Cranes
"E" = Storage Warehouse 100'x400'-Five or Six Stories-Crane Connection to "D"
"F" = " " 100'x350'- " " " " - " " " "
"G" = " " 100'x1600' " " " " - " " " "
"H" = Bulk-Freight Dock-Gantry Cranes
"J" = " " " Covered Storage-Bridge Crane
"K" = " " " Open " " " "

FIG. 124.—Proposed Canton Terminal, Baltimore. The Oyster Fork Quay Pier with stub end tracks.

laid out the tracks that way in designing a compact one-story transit-shed warehouse job, but if so, it has not yet been brought to our attention.

Three terminal track arrangements are shown in Figs. 122, 123, and 124.

DRAYWAYS

Teams and Motor Trucks.—The other movement from the pier, after the lighter and the railroad, is by dray or motor truck. This movement, except in the case of railroad freight at Manhattan, is much the smallest of the movements of the cargo.

The congestion on the railroad piers at Manhattan is due to the fact that the piers cannot carry sheds of sufficient area to accommodate the

freight, and in addition teams and drays are permitted on the piers to load parcels for the consignees. The wide pier, as at Philadelphia, with ample deck room on each side of a roadway, would be the solution. With such piers it would be possible to drive to the loading point and receive the parcels from a loading platform of wagon-bed height. In this case the car-floats would not be of the platform, twelve-car type, but of the eighteen-car type and therefore more economical. Freight would be unloaded directly to the pier. Congestion would be eliminated because of the free movement of the teams down the center roadway to the point opposite the merchandise to be loaded.

This is not possible on narrow piers which have no provision for teaming space, or on piers whose principal movement is by rail. The solution is to move the freight, by mechanical means if possible, as described in the chapter on Carting,[1] to the bulkhead house. This is the building at the entrance to the pier and extending along the bulkhead. This loading platform at the bulkhead should be reached by telpher or electric truck. There should be a loading platform of dray height. This platform is shown at a Philadelphia bulkhead (Fig. 125.) Electric trucks serve as the connection between the distant pier and the head house. However, excluding drays from the pier necessitates rehandling from point of rest to tail board.

George S. Webster, Director of Wharves, Docks and Ferries, Philadelphia, at a meeting of the Engineers Club of Philadelphia, in a discussion on ports, made these remarks:

> The piers as planned (in South Philadelphia, Moyamensing Group) are of ample width to accommodate all business that we believe will come to them. We find that those who handle trucks in the city of Philadelphia have very much less objection to going several miles to a wide pier where there is no congestion and delay than going to a pier immediately on the waterfront where, because of congestion, they may wait for several hours or even an entire day to unload.

In the case of railroad freight at Manhattan, this head house delivery to drays would be a large job. However, elsewhere, on analyzing the percentage of drayage of *maritime* freight it is seen to be about 20 per cent of the whole, and this small portion should by all odds be taken to the head house rather than have the teams come onto the pier.

At the Bush Terminals the movement of freight is analyzed as follows: 30 per cent is destined for the warehouse (by means of elevator truck or mule "lorry";) 25 per cent c. l. railroad freight (usually car-floated); 25 per cent l. c. l. railroad freight (usually lightered or car-floated); 20 per cent dray for local delivery.

At Hamburg the half of the freight which does not go overside in stream for barge transportation on the interior waterways, but over the quays, has the following distributions: 18 per cent by rail (c. l. and l. c. l.);

[1] MacElwee, "Port Development," Chap. XVI, p. 340.

FIG. 125.—Bulkhead platforms for the service of delivery trucks to keep the motor trucks and drays off the piers. Pier No. 36, Philadelphia. View looking south on Delaware Avenue.

20 per cent dray to local consignee (or l. c. l. to railroad); 45 per cent by lighter to warehouses or to river express barges; 17 per cent goes into barges over the quay after the ship has left or over the water side of the ship at the quay.

(*Photograph by the author.*)

FIG. 126.—Flush tracks permit delivery trucks to use the carloading platform when not occupied by railroad cars, Brooklyn Army Base.

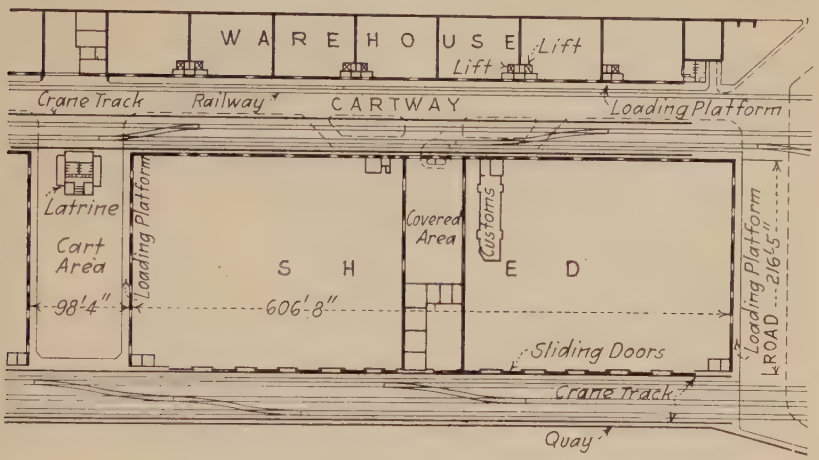
Drayway Solutions. *Flush Tracks.*—Various solutions have been brought forward to accommodate drays, both motor and horse drawn. Carts and cars are in conflict as claimants for space at the loading platforms. In addition to the casual use of the railroad-siding space where carts back across channel tracks laid flush with the pavement (Fig. 126),

(*Photograph by the author.*)

FIG. 127.—Regular cartage platforms at warehouse ends, Brooklyn Army Base.

there should be designed a shed-end dray platform. This cart-loading platform is illustrated by the warehouses in the Brooklyn Army Supply Base (Fig. 127). Also in various designs for transit sheds in a quay system, such space is to be noted. There is a fire break at speciged

intervals and a shed-loading platform between transit sheds at that point. These breaks may occur every 500 feet. This cart space serves several purposes. It is placed at the crossovers of the tracks on the wharf apron and in the rear of the sheds, therefore, at a point where there is the least activity. This point of least activity, therefore, falls at the ends of 500-foot ship berths. It further serves as a means of access for carts to the wharf apron, if desired, although the practice of admitting horse or motor trucks onto the wharf apron is decidedly undesirable. This combination fire-break and car-loading space will not offer a large amount of tail-board platform for truck dispatch.



Plan of Quay-Shed and Warehouse - No. 2 Dock

0 10 20 30 40 50 Metres

(Drawing from Dock and Harbour Authority.)

FIG. 128.—Cartway at Bremen. (1) Cartway 57 feet wide between warehouse and transit shed, (2) at ends of transit shed, and (3) in a specially provided covered area ca. 124 feet 6 inches by 52 feet 5 inches at the rear center of the transit shed. This shed is 606 feet 8 inches by 216 feet 5 inches. The end court or fire break trucking space is 216 feet 5 inches by 98 feet 4 inches.

The Shed End.—The wide transit shed with a middle driveway, as used at New Orleans, is effective. The transit shed is of such a width as to allow ample room for loading and discharging the ship in the bays toward the river. There is a narrow longitudinal bay in the center of the structure that is used as a driveway, but is not depressed. The rear bay of the transit shed is used for short-time storage and in loading and discharging freight cars. The breaks at the ends of the transit sheds afford entrances and exits for the trucks. Carts enter at one end and leave at the other.

The Cart Court.—At Bremen (Fig. 128), where very large transit sheds are installed, an inner court is provided approximately in the center of the shed. Drays pass over the parallel tracks and into a court

about 125 by 52 feet to loading platforms within the shed. This method is used frequently in freight and passenger stations in the United States. In addition, there are drayways about 98 feet wide, including platforms, between sheds. Also there is a 75-foot street between shed and warehouse.

Separate Drayway Level.—A separate level for motor trucks is provided at the Commonwealth Pier in Boston by means of a ramp. This serves to permit drays to cross the belt railway tracks at an upper level. The ramp, or viaduct, is expensive to construct and also it is frequently difficult to find sufficient room for the approaches. The principle involved is shown in the case of the second story of the pier of the Norfolk Supply Base. In this case, however, the ramp was constructed not for motor drays but for troop movements.

Inshore Dray Platforms.—The development of the large-wheel, platform-lift, electric-industrial truck, such as advocated by Willard C. Brinton (Fig. 102), solves the drayway problem at terminals by removing the drayways entirely from the terminals. This large-sized and fast electric truck passes over intervening rail tracks to a loading platform for carts at a distance from the working wharf.

The telpher transfer to truck tail-board was suggested some years ago by the late Calvin Tomkins, then Commissioner of Docks in New York, as a solution for the trucking problem in West Street in which the car-floats and piers form a very congested and inadequate delivery yard. In this case, the telpher, traveling overhead through unoccupied space, moved freight from box car to a truck-loading platform on the main level while spur tracks of the belt railroad were carried on an elevated track system. This installation is expensive, but the volume of traffic and the losses by congestion of the present system justified a great expense. This design in connection with movable-body, store-door-delivery, saw-tooth platform, and organized motor-truck system might be very efficient, providing all these elements could be brought together and made to synchronize. The lack of flexibility of the overhead monorail system in connection with the cost of its installation has been deterring to any efforts to put this system into actual practice.

CHAPTER X

THE WIDTH OF THE WHARF APRON[1]

The problem of the width of the wharf apron is part of the question of transfer and may be discussed here at this point. At the Chicago Convention of the American Association of Port Authorities in 1920, Captain B. C. Allin, Director of the Port of Houston, asked the Convention how wide the strip of wharf or space between the water's edge and the transit shed should be. Captain Allin, who was engaged in designing

Name of port	Existing apron	Desired for future construction
Boston	3 to 6 feet	No change contemplated.
New York	3 to 6 feet	Sufficient width desired to accommodate trucks, tractors, and trailers where railroad tracks will not be installed.
Philadelphia	3 to 7½ feet	7½ feet.
Wilmington, Del	6 to 8 feet	No change contemplated.
Norfolk	6 to 10 feet	15 feet.
Mobile	30 feet (with tracks)	No change contemplated.
New Orleans	13 to 19 feet	16 feet.
Galveston	20 to 25 feet	No change contemplated.
Houston	18 to 50 feet	16 feet.
Los Angeles	5 feet	16 feet.
San Francisco	10½ feet	20 to 21 feet, 8 inches (with tracks).
Portland	12 feet	16 feet.
Seattle	22 to 28 feet (with tracks)	28 feet.
Vancouver	16 to 24 feet	24 feet.
Quebec	9 to 22 feet	No change contemplated.
Montreal	8 to 10 feet	No change contemplated.

extensions to the port of Houston, was in search of information. To the astonishment of all the delegates to the Convention, no one present seemed to have any definite, established idea concerning the matter. Subsequently, Captain Allin directed a questionnaire to all of the important ports of the United States and Canada repeating his query, the

[1] The term "wharf apron," or "apron wharf," strictly speaking, is that portion of the structure carried on open piling back to the point of solid fill. In this discussion the term "wharf apron" is used to describe the portion of the wharf between water's edge and the transit shed.

results of which are given herewith in some detail.[1] The author, independently, has extended the investigation to many foreign ports and added the results of this foreign questionnaire as bases for our discussion. This list of replies to the two questionnaires is a digest of facts and not an expression of opinion as to what the width should be. Therefore, the author has made an effort to draw some definite conclusions as a guide to further discussion.

In brief, the usage at different American ports may be shown by the preceding table from the Allin questionnaire. The author's digest is in Table I, page 52.

It will be noted that the examples given are from United States and Canadian ports. They do not include the Supply Bases of the Quartermaster's Corps, United States Army, which embody much new thought and many innovations in marine terminal design in this hemisphere. These characteristics are included in Table I.

It will be noted from Table I that at most of the foreign ports and also at most American ports outside of the North Atlantic, transit sheds are set well back from the water's edge, giving an open-wharf apron of sufficient width to afford elbow room in transfer and handling and also space for ship-side rails, cranes, and other mechanical equipment. The wide variation in theories and practice would seem to indicate a wide field for analytical discussion not given much attention to date.

Upper Floor "Aprons."—The question of design of apron for the second-story floor level of transit sheds was submitted to the various port authorities and no definite expression of opinion given as to the type most generally preferred. Some prefer a set-back or permanent ledge; some a small balcony; others a platform traveling on a gantry; still others only the door sill. The same divergence of opinion and practice exists in other ports of the world.

With regard to the apron on the second story of the pier sheds (the former figures being for pier decks only), Allin's questionnaire yields the following summary:

Boston: No apron. At the Army base transit shed, none. Navy Pier, 3 to 7 feet.

New York: Sufficient to meet the needs of the traffic (*i.e.*, no answer at all).

Philadelphia: Balcony extending approximately 2 feet from the side of the shed.

Norfolk: (*a*) Inbound cargo handled directly into the shed without an apron; (*b*) outbound cargo a movable platform.

New Orleans: A small apron with special stevedore rigging. The Army Base wharf has a movable platform about 20 feet in width extending to the edge of the wharf.

[1] From an article by B. C. Allin, Major, Reserve Corps of Engineers, United States Army, in *World Ports*.

Los Angeles: An 8-foot permanent apron.

San Francisco: A movable platform (which obviates the necessity of narrowing the second floor. (Yet, in the China Basin water-side warehouse, the upper floors are set back.—The Author.)

Seattle: Movable platform (gantry).

Montreal: A 5-foot permanent apron.

It will be noted that the practice varies from 3 to 80 feet on main deck, and from 0 to 8 feet on second deck.

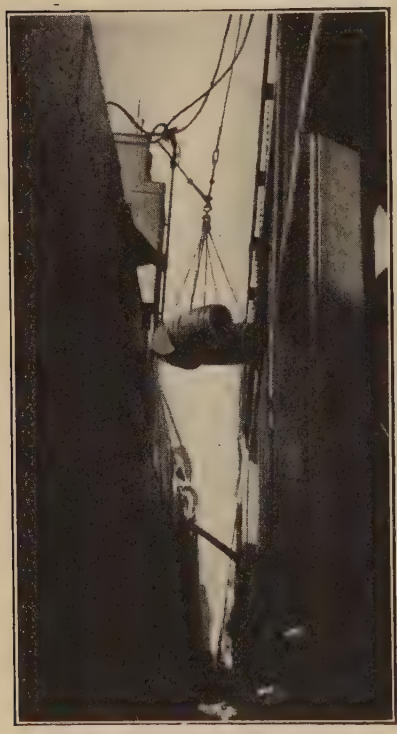
The Wharf Apron or String Piece in Undersized Piers.—Given first the type of narrow pile pier with one- or two-story sheds as found principally at Philadelphia, New York, and Boston, and illustrated by the photograph of Municipal Pier No. 9, at Philadelphia (Fig. 129), we have

(Courtesy of Dept. of Wharves, Docks, and Ferries.)

FIG. 129.—Wharf apron, Example No. 1. Narrow string piece illustrated by Cherry Street Pier No. 9, North Philadelphia. A single deck pier 535 by 100 feet with straight sides of transit sheds and string piece so narrow that ocean vessels with top hatches cannot be worked unless breasted off. This pier type satisfactory for side hatch coastwise vessels.

the following conditions: The piers are inadequate in width to carry a transit shed capable of sheltering the entire cargo of a modern ship, even when built to within 3 feet of the water's edge. The argument is therefore maintained that the transit shed on the pier should extend to the water's edge. There is not sufficient room for railroad tracks, cranes, or other shore devices, except perhaps electric pier deck winches. An ocean-going, top-hatch ship moored directly against the side of a pier of this type is too close to the shed to permit the rapid hoisting and lowering of drafts. The writer has watched this process at the Chelsea piers in New York (Fig. 130) and at the Havana Dock Company's piers, Havana, Cuba (Fig. 132), and many other places. The drafts invariably bang against the side of the ship and the outside wall of the pier shed, causing damage to the freight, wharf house, and ship. The photograph (Fig.

130) shows drafts of barrels being loaded at the Chelsea piers in New York, moving slowly and carefully through the narrow space between the ship and pier shed. In this case the pier is of the two-decked type. The usual practice is to breast the ship off sufficiently far to allow coal lighters for bunkering or floating cranes and elevators to work between the ship and the pier. A ship, breasted off from a pier in order to be



(Photograph by the author.)

FIG. 130.—Wharf apron, Example No. 1. At the Chelsea piers, New York. The ship is not breasted off and the space between pier shed (2 decks) and freeboard is so cramped that slings of cargo (barrels with cant hooks) are handled with difficulty and at reduced speed.

(Courtesy of Department of Wharves, Docks, and Ferries, Philadelphia.)

FIG. 131.—Wharf apron, Example No. 1. A 6-foot string piece, with drafts operating to balconies extending 2 feet from the side of the transit shed at the second deck.

able to work its tackle rapidly, is not solving the question of the string piece thereby, except by encroaching upon the waters of the slip. Inasmuch as the slips are too narrow as well as the piers, this is robbing Peter to pay Paul. This makes extremely difficult the lighterage operations that are essential in most ports, in particular for heavy lifts, because there is no equipment for handling heavy lifts over the piers from open

car to hold, and these must be handled from the water side by floating equipment. Therefore, if the ship must be breasted off from the pier in order to work the pier cargo, it reduces the efficiency of the important lighter service by decreasing the water area available in the slip. At the Port of Havana Dock Company, the ship is breasted off about 6 feet.

Pier No. 40, at Philadelphia (Fig. 131), shows a 6-foot string piece on a modern double-deck pier shed with cargo masts. In this case, flour is being handled between the second story of the pier shed and the hold in web slings on the burton, or union purchase system, and both whips are operated from deck winches aboard ship. It will be noted in this case that Pier No. 40 is equipped with small balconies on the second floor

(Photograph by the author.)

FIG. 132.—Wharf apron, Example No. 1. Port of Havana Docks Company, Cuba, string piece of two-decked pier extended by two rows of timbers and ship breasted off several feet.

to facilitate the landing of drafts at that point. Net slings are placed between the ship and the second-story shed balconies, in case a line should break. Utilizing the balcony and the opening into the second pier deck as a point of deposit for the drafts, it will be noted that the drafts have a free swing entirely above the gunwale of a vessel, and there is nothing to interfere with a rapid working of the falls. It is obvious, however, that even with a 6-foot string piece and the ship fairly light and high out of the water, the transfer movement would be slowed up materially in operations to the main deck of the pier because of the lack of space between shed and ship's freeboard.

Wharf Aprons and Ship-side Tracks.—The one-track string piece (Fig. 133) showing the McKean Street Pier No. 78, Philadelphia (also in cross-section Figs. 115, and 116), corresponds with the prevailing preference of 16 feet "desired for future construction" mentioned so frequently in replies to Allin's questionnaire. This width will accommodate one railroad track. Short piers serving one ship berth on each side will find (with certain reservations) one track sufficient.

Should Ship-side Tracks Be Depressed.—The question now arises, should these tracks be depressed, that is, should the deck of the pier shed be 4 feet above the wharf apron? In the McKean Street Pier, Philadelphia (Fig. 115), the tracks were depressed, but the rails were not laid flush with the string piece. Also there was built a high coping of concrete along the water's edge, equipped with a crane rail for a future semiportal gantry installation or a movable landing platform. As has subsequently worked out, this arrangement of a single depressed track rendered the string piece useless for any other purpose than handling heavy freight from open-top cars. As described elsewhere, the larger portion of miscellaneous cargo of a ship cannot be handled in this manner direct from car to ship, but must be assembled in the pier shed or on lighters. This design of a single depressed track on the wharf apron resulted in creating a "sunken road of Waterloo" between the pier shed and the ship. The writer has observed that in practice, when loading or landing general cargo, the *sunken road* is filled in or bridged over by drilling in flat cars that serve as a point of deposit across this *ditch*. In subsequent construction, this wharf apron was made 4 feet below the deck of the pier shed, but channel rails are used flush with the planking of the wharf apron, giving a smooth working deck from the loading platforms to the water's edge.

Under these circumstances, the *sunken road* to a large extent is made less of a trap. However, the 4-foot difference in level between the wharf apron and the floor of the shed is a hindrance in the movement of freight from point of deposit to the resting place in the transit shed, and the depressed portion of the wharf apron becomes practically useless as a working area. This mistake was made repeatedly at Hamburg and Bremen, but the quays are equipped with cranes that lift the drafts across the ditch. Ship's tackle cannot do this except with cargo mast burtons and then only up to narrow limits.

Depressed Wharf-apron Tracks at San Francisco.—These differ from the above Philadelphia system in that the wharf is considerably wider with an ample (10-foot) runway or outside platform between track and water. The track depression is provided with a ledge along both sides to receive heavy planks that are quickly laid opposite the ship's hatch to bridge the track depression. When not occupied by cars, the

(*Courtesy of Department of Wharves, Docks, and Ferries, Philadelphia.*)

FIG. 133.—Wharf apron, Example No. 2. A 16-foot string piece carrying a single, depressed track (Pier 78, South McKean Street) illustrating "The Sunken Road of Waterloo" applied to cargo handling.

(*Courtesy of Port of Portland, Oregon.*)

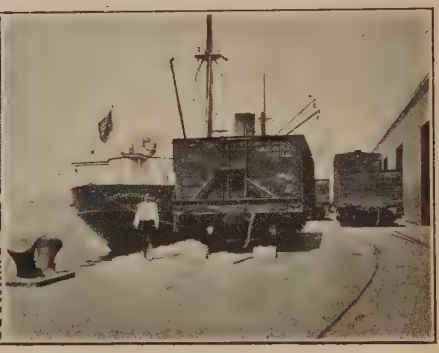
FIG. 134.—Wharf apron, Example No. 3. Municipal terminal No. 4., Pier No. 1, Port of Portland, Oregon. A two-track, wharf apron, flush-laid tracks, working space between, using inside track for box cars (of apples). Loading ship direct across apron, water side track used for shifting. Cargo burton masts not being used.

tracks are covered over (Fig. 135*a*). These piers are single width and carry no other tracks.

What seems to us to be better practice was followed in the design of the tracks on the wharf apron at Portland, Oregon (Fig. 134), at Charleston Army Supply Base (Fig. 140), and Norfolk Army Supply Bases (Fig. 136), and several other examples. In these cases, the wharf aprons and the floors of the wharf sheds are on the same level. But these are all double-pier or quay layouts of considerable length while the Philadelphia and San Francisco examples are comparatively short piers.

(*Photograph by the author.*)

FIG. 135*A*.—Wharf apron, Example No. 2. Depressed wharf apron tracks at San Francisco with ledge to receive bridging planks.



(*Photograph by the author.*)

FIG. 135*B*.—Wharf apron, Example No. 3. Double wharf apron tracks at the new Municipal Pier, San Diego, Calif. Note Cross-over and dead-end arrangements.

The fallacy in the reasoning that led to the adoption of a 4-foot difference in level between the wharf apron and the floor of the transit shed lies in the intention to use the wharf-apron tracks for loading and unloading cars in and out of the transit shed. A single track on a wharf apron is only justified as a means of loading bulky commodities direct from car to ship, as discussed under Chap. IX. Miscellaneous or general cargo in smaller packages (under 1,000 pounds) from box cars should be handled from the inshore side of the transit shed and should not come onto the wharf apron at all while a ship is being worked, until ready to be slung and stowed. These water-side tracks should not be used for box-car freight into and out of the transit shed except at such times as the berth is empty, or, in rather rare instances, where the box-car freight is simply topping off. This is bearing in mind that a ship can load or discharge freight four times as fast as the cargo can be loaded or discharged to and from box cars. This fact almost entirely precludes box-car-ship transfer

except refrigerated freight where the factor of even temperature to avoid spoiling outweighs the factor of speed. In assembling cargo before the arrival of a ship or removing it after the ship has discharged and left the berth, the water-side tracks may be used, in addition to the inshore tracks. This use is secondary, however, while the primary function of the wharf apron is to facilitate trucking between the resting place within the shed and the transfer hook at ship side.

(Courtesy of Director A. G. King, Port of Norfolk, Va.

FIG. 136.— Wharf apron, Example 3, Army Base, Norfolk, Va. Crane rails installed but no cranes, forces first track too far from ship making transfer difficult except for ships with long booms. U. S. S. B. Steamship *St. Anthony* discharging wood pulp.

The cargo masts and deck winches may be useful in transferring heavy packages from the transit shed to open-top cars on the wharf apron. Therefore, the advantage to be gained by a wharf-shed floor, on a level with the floor of the box cars that may occasionally use the wharf apron, is greatly offset by a disadvantage of a 40-inch difference in level between the wharf apron and the floor of the shed. When box cars on the

wharf apron are loaded from the shed, portable electric conveyors and electric-tractor cranes will do the lifting.

An excellent example of the advantage of a one-level, shed-floor, wharf apron is shown in Fig. 136 at the piers of the Army Base at Norfolk. The apron carries a crane rail, for semiportal gantry cranes that were never installed, and two railroad tracks in channel rails laid flush. The United States Shipping Board steamship *St. Anthony* is discharging wood pulp in bales and has gotten ahead of the truckers. With ample space on the wharf, however, the slowness of the shore gang has not retarded discharge of the ship. As usual, in wide wharf aprons designed for cranes and fitted with cargo masts, the ship is using its own tackle entirely and not the shore masts.

With wooden wharf floors that were laid of untreated material in wartime haste, the deterioration has been rapid, especially along the tracks, making of them a trucking hindrance greater than would have been necessary with channel rails properly laid in concrete. At several points, iron plates have been laid to bridge over these track grooves to facilitate the crossing with the small-wheeled hand trucks.

Wharf-apron Tracks on Greater than 13-foot Centers.—Wharf-apron tracks need not be laid on the usual 13-foot centers. The usual method is to facilitate door spotting of cars for two- and three-track loading. As this work is done at the center of wide piers and on the inshore side of the transit shed in the quay system, the wharf-apron tracks are for casual, not regular, loading and unloading of cars. Also with no loading platforms on the apron, there will be no trucking there. At Portland, Oregon (Fig. 134), the tracks are close to the water on one side and to the shed on the other, leaving a working space on the wharf between the tracks.

Water-side Tracks Should Be Close to the Water.—It must be borne in mind that water-side tracks should be close to the water. The object of cars at ship side is to facilitate direct transfer of heavy or bulky packages between car and ship. In most cases, dependence for transfer is on ship's gear, and no cranes are provided. Therefore, the tracks and open-top cars on them should be close enough to the water to enable the outboard boom set at the most efficient working angle to plumb the center line of the cars. Otherwise, the booms must be lowered to reach farther outboard and cannot lift so much. Also slinging of drafts or unslinging is difficult when the car is off center from the point of deposit.

Wide Car-loading Working Space at Ship Side.—There is an obvious advantage in the possibility of unloading box cars at ship side to a wharf space only a few feet from the ship's hook. The Commodore Point Terminals for general cargo at Jacksonville, Florida, are designed to do this. The questions involved are open to discussion. Cars are

drilled in on the ship-side track and unloaded onto the wharf apron until needed for transfer and stowage. When needed, the parcels are right at hand. To facilitate this short movement from pile to sling, the transit shed is set back 80 feet from the water. The terminal operators are much pleased with this arrangement. The object to be obtained is obvious, that of short trucking of merchandise. The objective is a valuable one, but the various combinations and counterbalances may be profitably analyzed. To discuss the Commodore Point Terminal wharf apron will lead into other examples and combinations.

At Jacksonville, the rails for one track (there should always be two at least on any wharf of more than one berth) are set flush with the deck, but the tracks are not depressed to enable trucking from loading platform into the car at floor level. This is correct because the sunken road on the wharf apron would be a greater disadvantage than the additional cost of lifting every package loaded into the cars 3½ feet from the wharf deck. Bear in mind again that the equipment now under discussion is for general cargo into box cars, not the transfer of heavy lifts between open-top cars and hold by ship's tackle or crane. Also in the case in point, there are neither cranes nor cargo masts (which would be useless 60 feet back). The transfer movement is done entirely by ship's tackle. To be within reach of ship's tackle for open-top car transfer, the track should be as close as possible to the ship. But the space thus occupied by the track is the same strip on the wharf at the ship's side that is essential as the point of deposit and pick-up by the tackle of the drafts being loaded or discharged (see also Fig. 134). It is obvious, therefore, that box cars cannot occupy the ship-side tracks during the time the ship is loading or discharging, because the ship's tackle cannot reach over and past the cars. Also it rains even in Jacksonville, or the sun may be hot, and with an 80-foot wharf apron there is no protection. Therefore, when all is considered, the objectives to be attained will be better realized with a narrower apron, emergency ship-side tracks and more shed tracks inshore.

Climate and Exposure.—At Jacksonville, it is claimed that the 80-foot open-wharf apron is possible because of the open climate. This is also the claim in South American ports. The climate of the South Atlantic and of Southern Pacific ports is salubrious; Charleston and Los Angeles vie for first place with a 10-year average of 70 and 71 per cent of possible sunshine hours. But that other 29 per cent at southern ports, when it does rain! It is, therefore, not recommended as good practice to unload general cargo from box cars onto an 80-foot open wharf on the assumption that hand trucking may be saved by accumulating cargo in the open in this manner where the merchandise is exposed both to tropical downpours and to subtropical sun. It is far better to move up the shed and then extend the sheltered working and ship-side storage

area by means of a wide cantilever marquise until all but 6 feet of the platform is covered.

The Very Wide Apron with Cranes as at Rio de Janeiro (Figs. 137 and 138).—The moment quay-side cargo cranes are introduced, there is a change in the situation. It will be noted at Rio de Janeiro, and also to a lesser degree at Hamburg and several other modern ports, that the quay-side tracks are depressed and the cranes transfer cargo between hold and wharf over the tops of cars to the car-loading platform, at car and transit-shed floor level. The moment cranes are introduced into the picture, there is a new and much more flexible situation. At Rio de Janeiro,

(Courtesy of U. S. Trade Commissioner, W. E. Embry.)

FIG. 137.—Wharf apron, Example 4. Eighty-two-foot wide wharf apron with three tracks offering special difficulties as both standard gage and meter gage rolling stock must be accommodated. Rio de Janeiro.

with an 80-foot wharf apron, full-portal cranes are used, spanning the outside track with the second and third tracks inshore from both crane legs. The tracks 1 and 2 are then more than 13-feet centers. If there are two tracks only, this would preclude double spotting, *i.e.*, the loading of two strings at one shift by trucking through one car to reach the car on the next track. But at Rio de Janeiro there are three tracks, which gives a complete set-up of two strings next to the transit shed and a running track or heavy-lift track between the crane legs at ship side. At Hamburg, with only one and occasionally two tracks, and a fairly compact apron, half-portal gantries are used, as the transit-shed crane rail is not an excessive distance from the water-side crane rail. At Bremen, the 55-foot wharf apron carries three depressed tracks, a loading platform and a half-arch gantry crane (Fig. 92).

The sunken road difficulty is not entirely obviated by cranes that whisk the loads through the air across intervening space. While recog-

nizing the disadvantages of extending this break transversely as well as laterally, it is suggested that the paved-track area at ship side 40 inches (or 20 inches as at Rio de Janeiro) below the rest of the quay, be connected with the transit shed by easy-grade ramps 12 to 14 feet in width and spaced on 250-foot centers, corresponding with the track cross-overs, or even closer intervals. But where cranes are used, there is no reason for depositing packages in the sunken road on the railroad tracks; such a situation would arise from some emergency. When reliance is placed on ship's tackle, without shore equipment the entire wharf apron should be one level with set-in rails facilitating trucking in any direction

(Courtesy of U. S. Trade Commissioner, W. E. Embry.)

FIG. 138.—Wharf apron at Rio de Janeiro is 81 feet wide, carries 90 cranes in a length of 3,355¼ meters (10,906 ft.) with 18 sheds and 3 railroad tracks. The wide platform before the shed (25 meters = 82 feet) carries small tracks for hand-pushed cars. Note especially that the cranes easily span the car tracks and transfer freight over the tops of the cars. The tracks are only half depressed.

without pitfalls. Therefore, it would seem that such ramps, intersecting the wharf-apron platform at right angles, would be more of a disadvantage than a gain.

The Cargo Mast and Wide Wharf Aprons.—It will be noted in Figs. 134, 136, and 140 that the cargo masts are not being used, the entire transfer being accomplished by the two-boom burton system of the ship's own tackle.

The cargo masts at Charleston (Fig. 140) are more than 100 feet above the water level, while those at Portland (Fig. 134) are much lower. The problem involved here is the mechanical force necessary to work a burton-and-fall system from low-cargo masts across a wide wharf apron. A union purchase requires increasing power in operation as the angle formed by the two ropes widens ($M = D^2$). It is inefficient to work cargo masts and ship's booms if the apron is wide, because the cargo masts must be increased to excessive heights.

The "snow scene" of the Philadelphia Quartermaster Terminal (Fig. 139) was caused by the breakage of flour bags due to inefficiency of the working angle of the burton tackle from shore shackles attached to the low cornice roof crane rail across a very wide wharf. It will be observed that in this three-story shed there is a crane rail along the face of the shed at the level of the second deck. The wide wharf apron, with two tracks, was designed not for cargo masts, but for equipment with semiportal gantry cranes spanning two tracks. Two tracks are necessary because of the length of this pier. As the Armistice interrupted the work, the cranes were never installed. The terminal was also designed

(Photograph by the author.)

FIG. 139.—Wharf apron, Example 5. Snow scene produced by flour from bags burst in loading flour across a very wide wharf apron producing an inefficient mechanical movement in the two ropes of the union purchase. There was no choice in the matter with the flour stowed on the third deck as lowering and trucking to ship side would have cost more than the damages. Army Supply Base, Philadelphia.

to carry roof cranes, which were never installed. There being no mechanical installation available, shackles and blocks were attached to the roof crane rail to serve in the place of the cargo mast. The height of the roof, however, was not sufficient to give an effective working angle to burton across a wharf apron 38 feet wide. The steamship *Eglantine*, loading flour from the second story of this terminal, encountered great difficulty in lifting the drafts with the falls forming an obtuse angle across so great a distance. Due to the fact that the ship's winches could not handle the whips at this angle, the bags of flour—a tender cargo at best—were frequently banged against the ship's sides, bursting open the bags and covering the apron with a thick coating of flour, the cause of the snow effect of the illustration. The stevedores and others lost heavily for damages, but were helpless to do otherwise as the cargo was stowed in an

upper floor and could only be transferred across the wide apron by the burton method or by trucking to elevators, and then roundabout across the apron. This would have cost more labor than the damages involved.

The Charleston Base has a wharf apron 40 feet wide (quay 2,160 feet long). Although the wharf apron is wide, the cargo masts are usable because of their great height of more than 100 feet. They are seldom used, however. This applies to all the installations of cargo masts with wide aprons.

The relation between wharf width and cargo mast may be stated as a theorem: As the wharf apron is widened, cargo masts may be retained if increased sufficiently in height. Beyond a width of apron of 30 feet, the height of the masts and the energy necessary to operate the burton will increase the costs of construction and operation beyond the point of economic advantage of this system of transfer.

Two Tracks and Crossovers on Long Berthing Spaces.—The principal examples single, wharf-apron tracks are Philadelphia, Pier No. 9, which shows a length of 535 feet and a width of 100 feet. The McKean Street Pier with a length of 900 by 250 feet and Pier No. 86, a length of 900 by 300 feet. When wharf aprons or string pieces are longer than a single berth for one large cargo ship, an awkward situation arises with regard to the ship-side track. Delays will be caused by the necessity of waiting for all of the cars on the wharf aprons to be loaded or discharged before pulling the string of cars and setting a new string. In fact, there is no intermediate pier length between a single-berth wharf and a two-berth wharf. When a wharf is long enough to accommodate two full-sized cargo vessels, we are confronted with the dilemma of one set of cars serving ship No. 1 obstructing and delaying operations of the cars serving ship No. 2. This also applies to the loading platforms on the inshore side. It therefore becomes necessary to widen sufficiently the wharf apron serving two berths to permit two tracks with frequent crossovers in order to pull and reset strings of cars at any one ship without delaying work on the other ship. In fact, cars should have crossover facilities for each pair of hatches. Therefore, in extended wharf lengths of the typical marginal quay design, we would find two, and in long quays even three, sets of tracks on the wharf apron, and the width of the wharf apron increased to at least 28 feet to accommodate these tracks. In the case of the new works at Brisbane, Australia, the Chief Engineer, in criticizing the plan, states: "With a length of 5,800 feet of quay, three tracks would be preferable to the two that were designed." Unless ample facilities are given for crossovers from the face of the wharf to the main leads of the tracks at the rear or inshore side of the transit shed, this is undoubtedly a just criticism. Also there should be numerous crossovers to facilitate switching. There should be a crossover opposite the center of each ship's berth and between berths. Considering vessels of 500 feet in

(Photographs by the author.) a b c

FIG. 140.—Wharf apron; Example 5, Charleston Army Base.

length, there would be a crossover approximately every 260 feet, which allows 20-foot clearings between vessels.

It is customary to assume that a vessel berth is 500 feet, as most cargo vessels are less than this length. In this case, we could easily assume that the crossovers are 250 feet apart, or two to each 500-foot berth, and there will still be ample clearings. These dimensions are, however, empirical with regard to the crossovers, as the vessels will vary in length by 100 feet more or less from the present standard of calculation, 500 feet to the berth. An average of car lengths is taken to be 42 feet. Average box-car ladings, 20 tons, average car-floor heights, 40 inches. Two strings of twelve cars each set double with doors spotted will occupy slightly more than the length of a standard berth, namely 504 feet.

In the design of the Army Base at Charleston, the arrangement with only one track on the 2,400-foot open wharf has been found to be extremely inconvenient in operation, and efforts must now be made to install additional trackage in order to work the ship-side loading tracks in a satisfactory manner. This is a good practical example of error in designing only one ship-side track on a long quay.

Prodigality with Wharf-apron Space.—This example of the Charleston Army Base serves to show a number of facts in the discussion of wharf-apron widths. This apron is 40 feet wide, from water's edge to transit shed; yet even with this width and a total length of 2,400 feet there is only one single track (Fig. 140). The one track is spanned by four full-portal, heavy-duty electric cranes. It will be noted that the gantry of the crane is massive and the gage of the two crane tracks extra wide. Beginning with the water's edge (Fig. 140), it will be possible to redesign this apron so

as to reduce this width from 40 to 30 feet (25 per cent) and still have *two* railroad tracks instead of one. The string piece, with mooring-line bollards, is 2 feet. It will remain. The 2 feet between bollards and present crane leg (Fig. 140c) will be saved by moving the crane rail to 3 feet from water instead of 5 feet. It may be necessary to redesign the gantry leg with more wheels and less width of members. Also the full-arch gantry would be replaced by a half-arch gantry, thus taking one crane track off the wharf; then 8 feet from the center line to second track; then 7 feet from the center line to transit-shed wall; therefore $3 + 7 + 13 + 7$ feet $= 30$ feet.

It will be noted in Fig. 140, middle cut, that the space between the locomotive and shed is practically a dead waste, used only to store some unused equipment or for a tally clerk's movable desk.

Nicholson's Wharf-apron Width.—G. F. Nicholson, Chief Engineer of the Port of Los Angeles, gives 28 feet as the necessary width for a wharf apron; 8 feet to center of the first track, the two tracks to be 13-foot centers and the clearings of the second track with the wall of the transit shed to be 7 feet from the center line of the second track, a total of the apron 28 feet. However, 28 feet makes no provision for a crane rail. By adding 2 feet for one crane rail, the same total, 30 feet, is reached, the author's width.

SUMMARY

The problem is divided into two distinct cases: (1) when the wharf apron is on a short pier serving one vessel; (2) when the wharf apron is on a quay serving two or more ships.

The nature and the climate of the port and the predominating cargo to be handled over the wharf must be taken into consideration in designing wharf-apron width.

The track or tracks on the wharf apron should be flush with the wharf and with the transit-shed floor.

The wharf apron and the transit-shed floor should be on one level.

Wharf aprons on piers or quays serving two or more ship berths should be sufficiently wide to carry two or three tracks and be provided with frequent crossovers between the tracks at intervals of 250 to 260 feet.

As the wharf apron is widened, cargo masts should be increased in height to give an efficient mechanical angle to the burton-and-fall. This increase in width of apron and height of mast quickly reaches the point of diminishing returns and the limit is about 30-foot span, 100-foot mast (above mean water level).

Where the possibility of intensive cargo movement is anticipated, cranes of the straight-line or semiportal gantry or roof types should be installed spanning the tracks.

Full-portal gantries are uneconomical of wharf-apron space.

The width of the wharf apron should be cut down to the lowest distance between ship and transit shed that it is possible to design and make provision for adequate car shifting and freedom of action in rapid-transfer movements.

The width should not be reduced at the cost of ship-side tracks and mechanical transfer and handling.

Provision for one crane rail on the apron and one on the face of the wharf shed should be made to make it possible in two-deck piers later to install mechanical equipment, movable loading platforms, movable passenger gangplanks, etc., even when not included in initial plans.

The Answer.—The reply to Captain Allin's question, "How wide should the wharf apron be?" follows:

1. Short piers serving one berth, 16 feet.

2. Long quays serving several berths, 30 feet (*i.e.*, 30 feet 6 inches from the water's edge to the center of the first row of shed columns or 30 feet center coping to column footings).

NOTE.—J. Russel Wait, General Manager, Port Utilities Commission, now operating the Army Base, defends the 40 foot apron. He would use even a 50 foot width in special instances. In handling tierces of leaf tobacco, lots are frequently mixed when arriving at ship side for loading. All lots must be complete and checked before loading. To move the heavy tierces into the shed for segregation and back again to ship side involves double handling. Therefore a roomy wharf apron has proven in practice to be convenient and economical. The same question of segregation applies to export cotton. This all goes to prove that circumstances alter cases.

CHAPTER XI

THE PORT TERMINAL WAREHOUSE

A warehouse is a reservoir to make up the irregularities of seasonal and traffic fluctuations in commerce. It is obvious that the world production of staple commodities is irregular. There are seasonal movements of sugar, cotton, wool, coffee, and many other commodities. In order to gather together and hold the season's crop until it can be gradually consumed throughout the remainder of the year, some sort of reservoir is necessary. Business organizations that perform this service of concentration and redistribution are economic functions of the first magnitude in modern civilization. The physical warehouse equipment is a fundamental facility at ports.

Warehouse Services for Traffic and Commerce.—Services performed by warehouses fall into three main categories that must be kept clearly in mind in further discussion of this subject: (1) storage for merchandising; (2) storage in transit; (3) storage for financing. A description of the functions of the merchandising warehouse, first, may serve to elucidate more clearly the storage in transit.

Storage for merchandising usually involves the storage of goods in the merchant's own warehouse, in a warehouse which is constructed and built by the merchant for his own use, or in warehousing space leased by the merchant from a warehousing company for a period of time. In this case, the merchant controls his own space under certain warehouse regulations and remains in possession of this allotted space whether his stock of merchandise fills it or not. He uses the space not only for storage but often for displaying samples, for recoopering, repacking, relabeling, and other manipulations in the course of carrying on his business. Take, for example, the Yale and Towne branch in Hamburg. That company had a certain number of square meters of space, rented from the Free Port Warehouse Company in the free port of Hamburg, into which stocks were accumulated, shipped from Stamford, Connecticut, and from which they were reshipped to various parts of Europe, as the merchandise was sold. This space was occupied permanently by the Yale and Towne Company and used in the merchandising of their products throughout the market under jurisdiction of that office. Not very far away, in the same area, was the warehouse space rented by the European agent of the Adriance-Platt Harvesting Machine Company. Max Leichsensring, on the Sandtor Quay, had a certain space which he had

occupied many years and into which he imported coffee; blended, repacked, relabeled, and shipped out as occasions in the business warranted. These few examples will illustrate definitely what is meant by the term "merchandising storage." It is storage incident to the sale of goods.

Storage in transit refers not only to goods that may be held in storage under the "storage in transit privilege" of the through bill of lading, but includes any storage incident to a transportation movement. Such storage usually occupies only that specified space required for the particular shipment. It may be caused by failure of a rail shipment from the interior to reach a ship before sailing date. It may be due to controversies arising regarding merchandise. It may arise from the removal of merchandise from wharves to general stores under the 48-hour rule. It may take on certain aspects of merchandising storage when advantage is taken of the storage in transit privilege to hold goods in storage pending further orders for the disposition of the merchandise. But primarily it is storage incident to the movement of the goods in transportation.

The difference cited is not a theoretical one. We are dealing with a very practical and not a purely academic principle. Thought on the subject will soon reveal the very important fact that a merchandising storage requires a greater flexibility[1] of movement with longer periods of storage and more infrequent movements of the merchandise in and out. Also it includes manipulation of the merchandise with regard to repacking, sampling, etc. On the other hand, the storage in transit movement is more closely confined to one steamship line and one railroad. The period in storage is usually of shorter intervals, often only a few days. And usually the goods undergo less inspection, handling, or other treatment. These facts, therefore, greatly affect the nature of the design and location of warehouses according to the nature of the traffic that they are to serve, transit or merchandising storage.

Warehouse Design and Credit.[2]—There is a direct relationship between the import and export business from the credit and financial standpoint in warehouse design. The facilities and cost of financing shipments of merchandise in foreign and coastwise or intercoastal trade depends upon three important factors in warehousing, all having to do with security.

Security against fire, which involves the construction of the building and its location with respect to other buildings as a fire risk. The more nearly fireproof the warehouse, the lower the insurance rates. The point of diminishing returns is reached when the capital investment in the

[1] "Flexibility" in this sense refers to the choice of a large number of means of transportation, dray, trolley, lighter, barge, coastwise, or offshore vessels.

[2] See also article by the author by this title in *Credit,* 1920. National Association of Credit Men.

building demands storage rates in excess of possible savings in insurance premiums.

Under this caption may be added other sources of deterioration such as leakage, drippings from sprinkler systems due to leaks or condensation, sweating due to lack of ventilation, rodents and vermin due to insufficient rat proofing, or general untidiness.

Security against Theft.—Warehouses in which goods are deposited on negotiable warehouse receipts (warrants) that are discounted by banks, must be so constructed and administered that the banks are assured that the merchandise will not be pilfered.

Security against fraud concerns the management and administration of the warehouses in which goods are held on issuance of negotiable warehouse receipts, such as unauthorized withdrawal of merchandise held as security for loans. Administration or supervision by the port authority, operation by a quasi-public corporation in which the port authority or port trust is thoroughly represented on the board of directors with jurisdiction to inspect, audit, and control, will give additional assurance that the banks will not lose through fraud, with resulting lower discount rates on the warrants.

Therefore, warehouses, to fulfil their function, not only as a place of storage but as an agency in the financing of business operations, must be so constructed and administered as to insure against fire and deterioration, theft and fraud. Given these things, it is possible for merchants to do a very large business on a comparatively small capital with the help of the banks.

Partial Withdrawals.—Various modifications of warrants or warehouse receipts have been developed to facilitate business. For instance, many large ship lines operating through the free port warehouses of Hamburg and Bremen issue a partial bill of lading certificate *Konossement-teilschein*, which enables goods stored in transit on a through bill of lading to be withdrawn in partial lots.

A similar application of the principle has been put in operation by the Lawrence Warehouse Company in California in financing shipments of canned goods. In this case, the warehousing company, through a bonded agent, takes over the control of the cannery's own warehouse, assuming responsibility for merchandise deposited therein for which a warehouse receipt is issued and discounted by the banks. When shipments are made, the canner issues an order for bank release, which is presented to the lending bank, with sufficient cash to satisfy the bank's claim on the portion of the goods to be released. The bank, having received payment for the portion of the amount stored, signs the release, which is presented to the bonded representative of the warehouse company, who counts out the shipment specified on the release. The cost of this service for the entire packing season amounts to about one-fifth

of 1 per cent of the sales value. Banks extend the limit of credit on warehouse receipts for the reason that such loans may be discounted with the Federal Reserve Bank, thereby releasing capital with which to finance further warehouse receipts. This easing of the credit strain, particularly in seasonal movements in any seasonal industry, stabilizes prices by liquidating the credit—in the instance just cited—so that the packer may not only make full use of his facilities when putting up the pack, but may distribute the sale over the rest of the year without being forced into bankruptcy in case his loans are called because of a money stringency.

Kinds of Warehouse Receipts.[1]—A warehouse receipt is an acknowledgment of the warehouseman that he has received on storage certain goods which will be delivered on demand, provided the terms of the receipt are complied with.

The Uniform Warehouse Receipts Act specifies two distinct forms of warehouse receipt, negotiable and non-negotiable. Each form has a separate function. Whether it be of the negotiable or non-negotiable form, each warehouse receipt must, in accordance with the law, specify:

1. The location of the warehouse where the goods are stored.
2. The date of issue of the receipt.
3. The consecutive number of the receipt.
4. A statement whether the goods received will be delivered to the bearer, to a specified person, or to a specified person or his order.
5. The rate of storage charges.
6. A description of the goods or of the packages containing them.
7. The signature of the warehouseman, which may be made by his authorized agent.
8. The fact of such ownership, if the receipt is issued for goods of which the warehouseman is owner, either solely or jointly or in common with others.
9. A statement of the amount of advances made and of liabilities incurred for which the warehouseman claims a lien.

If the precise amount of such advances made or of such liabilities incurred is, at the time of the issue of the receipt, unknown to the warehouseman or to his agent who issues it, a statement of the fact that advances have been made or liabilities incurred and the purpose thereof is sufficient.

The warehouseman, however, incurs liability for the omission of the foregoing on negotiable receipts only.

The two forms of receipts differ in actual use chiefly as to the manner in which right of possession of the goods covered by the receipts may

[1] See "Warehouse Receipts as Collateral," by the Committee on Banks and Warehouses, American Warehousemen's Association, Office of the Secretary, Pittsburgh, 1920.

pass from one party to another, and the manner in which delivery of the goods can be effected.

Negotiable Warehouse Receipts.—A negotiable receipt may pass from hand to hand merely by endorsement in much the same manner as any other negotiable instrument. Right of possession of the goods covered by a negotiable receipt follows the ownership and possession of the receipt. Lawful delivery of goods covered by a negotiable warehouse receipt cannot be made without the surrender of the receipt properly endorsed. Care must be exercised by the holder of a negotiable receipt that it may not be lost, misplaced, or destroyed.

Non-negotiable Receipts.—The surrender of a non-negotiable warehouse receipt is not required by law. Delivery of goods covered by such a receipt, or transfer of the right to delivery on the books of the warehouseman, is accomplished through the written order of the party in whose name the goods are stored. Non-negotiable receipts must be so marked. Failure so to do may require the warehouseman to treat such receipts as negotiable.

Warehouseman's Lien.—The warehouseman's lien for charges, advances, etc., may be enforced against all goods, whenever deposited, if stored under a non-negotiable receipt, but the lien is specific under a negotiable receipt, which must state charges for which the lien is claimed.

Adaptability of the Negotiable Warehouse Receipt.—A negotiable warehouse receipt permits transfer of right of possession by mere endorsement. The negotiable receipt by reason of the ease of negotiation has certain distinct advantages which do not obtain in the case of non-negotiable receipts. A banker may, with reasonable safety, accept as collateral a duly endorsed negotiable receipt issued by a reputable warehouseman, provided he is satisfied with the endorsements and is sure that the goods are as represented. Care should, of course, be exercised to see that storage charges and other liens are fully paid through having receipted bills of the warehouseman filed with him monthly. In case the borrower desires to take delivery of a portion of the goods covered by a negotiable receipt, it is necessary either to present the receipt to the warehouseman in order that there may be noted upon it the release of the quantity delivered, or to surrender the original receipt and obtain a new one for the goods remaining undelivered.

Adaptability of the Non-negotiable Receipt.—When money is to be loaned on goods in storage and the banker obtains a non-negotiable receipt in his own name, the goods are under his sole control. In such a case, the warehouseman will not permit delivery, or even inspection, of the goods without the written authority of the banker. In case the borrower is involved in litigation, an attachment of the goods will not prevail as long as the receipt is in the name of the banker. The banker assumes no liability or diminution of security in the event of loss, mis-

placement, or destruction of such a receipt, since the goods cannot be released without his written order. Partial deliveries can be made merely on the written order of the banker. Most of the warehousemen of the country issue non-negotiable receipts in exchange for negotiable receipts, or transfer goods covered by a non-negotiable receipt to another party, without making a charge for the additional non-negotiable receipt required.

Recommendation.—For collateral use the American Warehousemen's Association recommends the non-negotiable warehouse receipt in the name of the banker as compared with the negotiable form.

Delivery Orders.—In addition to the return of the negotiable receipt for complete delivery or endorsement of partial delivery, signed delivery orders are required by the warehouseman regardless of the form of the warehouse receipt. Delivery orders do not require any particular form, but care should be taken to see that they specify to whom the goods are to be delivered, the location and description of the goods as stated in the receipt, and the number of the receipt. The warehouseman is not obligated to deliver until his lien for storage and other charges is satisfied.

Transfer Orders.—When the right of possession of goods covered by a warehouse receipt is to be transferred on the books of the warehouseman, a signed transfer order is required. Such orders differ from delivery orders only to the extent that they refer to the transfer, rather than the physical delivery, of the goods. Transfer orders should contain the same information as the delivery order, and, to be effective, all liens of the warehouseman must be satisfied. Frequently transfer orders are held for a considerable period by the party in whose favor they are made; to avoid liability for additional charges, persons issuing transfer orders should state on the orders that all charges accruing subsequent to the date of the order are to be paid by the transferee.

Cooperation.—The American Warehousemen's Association is at all times ready and willing to cooperate to the extent of its ability in aiding bankers in matters pertaining to warehouse receipts, or general warehousing problems.

CONSTRUCTION AND LOCATION

Types of Warehouses.—There are two distinct types of warehouse construction—the single-storied or ground-storage warehouse, and the multiple-storied structures.

Single-storied warehouses are preferable where the ground is inexpensive and abundant. This type of construction, because of better foundations, is usually cheaper. If the foundations are reasonably well laid, the floor loads can be very great. Ground-storage warehouses are usually built with a greater roof-truss clearance than between floors in

the many-storied warehouse. This gives more height for tiering. The fact of greater floor load and greater height makes it possible to handle certain specialized freight by mechanical means, and therefore, at a lower cost. This applies to nearly all materials in bales, bags, barrels, and small uniform boxes. The limit to the height of tiering by mechanical means, even when containers of uniform size are being handled, depends upon the nature of the commodity, that is, its ability to withstand the pressure of the upper courses. For instance, bags of potatoes cannot be tiered very high because the pressure of the bags on top will ruin the potatoes at the bottom.

The single-storied or spread-out warehouse has a further disadvantage of longer trucking distances and greater supervision required to prevent theft. On the other hand, the single-story warehouse with heavy fire walls makes it possible to localize fires and reduce the fire hazard to the entire storage area. For this reason, among others, cotton warehouses are invariably single storied, not only because of the advantages in tiering and handling, but because of the fire risk. Also, a single-story warehouse has the advantage of better light and ventilation in large floor areas through skylights.

Multiple-storied Warehouses.—Most city warehouses are multiple storied because of the high value of land. There has been a gradual increase in the height and refinement of multiple-storied warehouse construction. The increase in height, once heavy foundations are necessary, is an added economy and brings a greater dilution of foundation and land values over the total storage space. This increase in height makes it possible to locate merchandising warehouses close to business centers and to bring about the most intensive possible use of bulkhead and upland waterfront properties. Such warehouses were formerly three to five stories high and rather primitive. Now warehouses are not infrequently of from ten to twenty stories. The desire for higher altitudes for offices has led to a utilization of the top floors of such warehouses for office space.

The principles of handling and storing in multiple-storied warehouses are quite different from those in ground storage. The floors are built fairly close together, even as close as 9-foot centers, more frequently 11 and 12 feet. As the floor loads are limited, merchandise is stored at a limited height, making high ceiling clearances unnecessary. There is no tiering above approximately shoulder height. The labor and time saved in high tiering is, however, absorbed in the time and expense of elevation or vertical transportation. The problem of interior elevation is important. The additional cost of vertical transportation, of heavier foundation, of more expensive construction in general, is offset by the high totals of floor area obtainable and the lower handling costs. As a result, the costs of construction and operation are not infrequently lower

for the square foot than in the case of ground storage. Multiple-storied warehouses also have greater ease of protection against theft and more thorough proofing against rodents and vermin.

A further advantage of the many-storied warehouse is the economy of land and trucking distances in the use of the entire ground floor, or the first two floors, for shipping platforms, both rail and truck. In a many-storied warehouse the ground floor may be entirely occupied by the shipping and receiving operations, and many times the ground area remains available for storage in the stories rising above.

The choice between the methods of many-storied and single-storied warehouses is, therefore, one of ground value, of initial capital investment, of local conditions, and nature of commodity to be handled.

VERTICAL TRANSPORTATION

Whenever a transit shed or a warehouse rises above the ground floor, the question of vertical movement becomes a problem. Much progress has been made in solving the problem of elevation, and as in the case of office buildings, the increased height of warehouses has been due to the increased efficiency in vertical transportation.

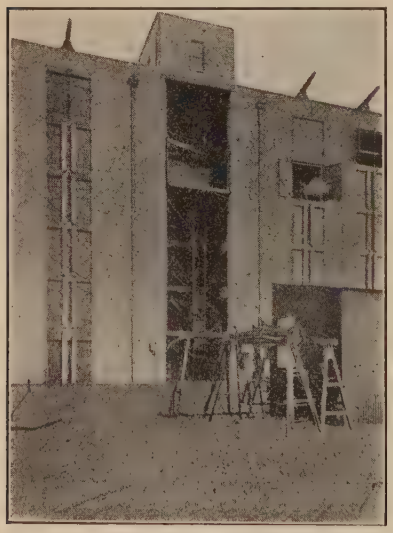


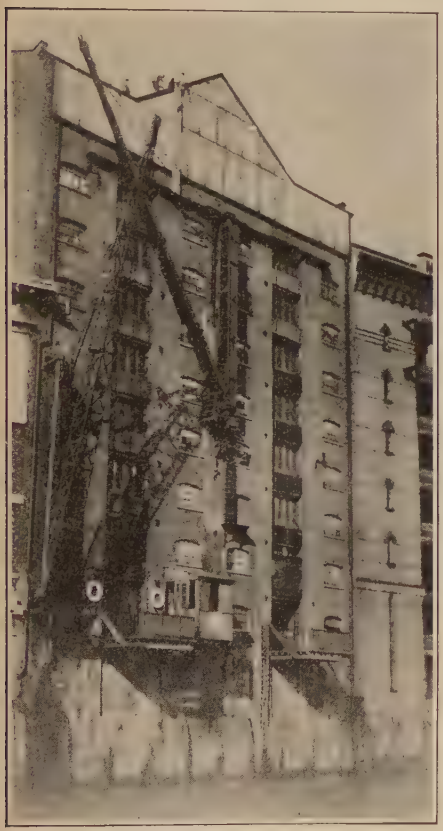
FIG. 141.—Warehouses and whip hoists at the Bush terminal.

Cornice Beams and Whip Hoists.—For only a few floors, the most approved hoisting or elevating machinery is not the usual lift or elevator as in factories and loft buildings, but the fall rope outside of the building. One system is the electric warehouse hoist with a drum and motor and controller in the roof space with a controlling lever at each floor served by the fall rope. It has been found to be more economical than the elevator.

The other is the so-called "whip hoist" with the winding drum. In older American warehouses the winding machinery is placed in front of the building instead of under the roof as in European examples. There is no control lever on the floor, but the control is exercised by the man operating the drum in front of the building, who has full view of what is going on. Electric hoisting winches are placed on the marginal way in front of the warehouse and about 75 feet distant from it. From the winch, lines run over the blocks above the warehouse door. One winch

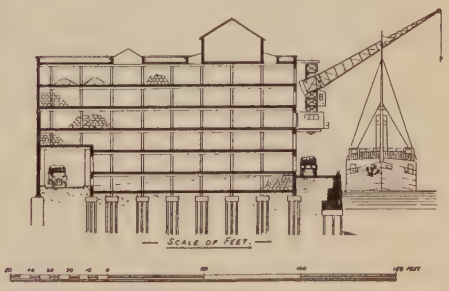
can operate four or more lines. Loads are hoisted directly from the marginal way under the warehouse opening to a little above the level of the opening, and then are swung into the warehouse floor. Eight hundred bags of coffee averaging 130 pounds have been raised by a single whip in an hour (Fig. 141).

The cornice beam carrying a block and tackle extending out from the eaves of the warehouse opposite the doors to the warehouse floors has been the method used for centuries. An important improvement was introduced at the warehouses of the free port of Hamburg, when these were constructed between 1882 and 1888, by the introduction of mechanical power to work the hoists. This power was hydraulic in the beginning and afterwards changed over into an electric motor and drum. Both were controlled by a hand rope at the side of each opening in the building and within easy reach of the warehouse foreman standing in the door and in view of the operations. In the Holland, Hamburg, and some other



(Photograph from C. of E., U. S. A.)

FIG. 142.—Wall cranes for outside elevation. Old waterside warehouses, London.



(Dock and Harbour Authority.)

FIG. 143.—Outside elevation by wall cranes (30 C. W. T.—80 feet, 600 minutes) at the new warehouses of Messrs. Butler's Wharf, Ltd., London.

European warehouses, merchandise is brought to the warehouse in lighters through canals and is hoisted directly from the lighter into the warehouse floor. It is evident that there is no place for an outside hoisting machine as that space is occupied by the canal.

Warehouse Wall Cranes.—In British ports and some continental ports, many water-side warehouses elevate their merchandise by means

of long-arm cranes attached to the face of the warehouse. The warehouses receive most of their cargo by lighter over docks or canals upon which the warehouses front, with or without an intervening wharf. An old-time London warehouse, with two such wall cranes, is shown in Fig. 142.

A rather unusual type of wall crane, carried on huge brackets extending from the second floor above the street level, is that of the new waterside warehouse of Messrs. Butlers' Wharf, Ltd., London (Fig. 143). This is indeed an interesting development.

The hoisting equipment consists of several 15-hundredweight electric winches and swinging jibs on the land side, and one hydraulic and five electric luffing cranes on the water side.

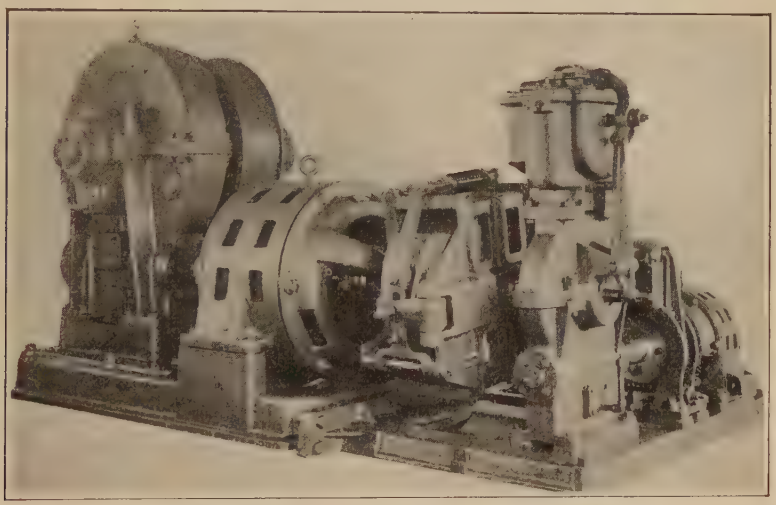
Both as to situation and design these electric cranes attract attention, and since they have a reach of over 80 feet from the warehouse front, they can deal with cargo as far out as a second bottom barge lying outside a ship alongside.

The cranes are of the Musker-Davison patent level-luffing type, provided with independent motions for hoisting, lowering, luffing, and sluing, all controlled from the operator's cabin placed at the front of the crane. They are capable of dealing with 30-hundredweight loads at a maximum radius of 74 feet; the minimum radius is 20 feet. One of the cranes is provided with additional gearing for lifting loads of 5 tons on a snatchblock, and two parts of rope at a maximum radius of 39 feet. The snatchblock is suspended from a point near the middle of the jib. The speed of hoisting 30-hundredweight loads is 200 feet per minute; luffing 200 feet per minute; and sluing 450 feet per minute at maximum radius.

The wall brackets supporting each crane are built of steel sections. The steel joists forming the lower bracket pass through the wall at a point immediately below the floor, and are let into and secured to the rear wall of the building. The distance from the underside of the lower bracket to quay level was made about 21 feet 6 inches to allow sufficient clearance for traffic passing along the quay, and, referring to the illustrations, it will be seen that the cranes leave the quay entirely free from obstruction of any kind. The top bracket is firmly secured to the steelwork of the roof of the building.

Microleveling Platform Encourages Interior Elevation.—In 1917 when "Ports and Terminal Facilities" was written, the author, based on his experience in the elevator business, was averse to any attempt at interior elevation in many-storied warehouses, in view of the loss in time and the wear on ropes, controller, contacts, and other parts of the platform elevators operating in shafts because of the difficulty in registering platform and floor. Subsequently, an invention in elevator machinery completely changed this entire situation. This invention was the micro-

leveling platform by means of which the platform of the elevator when brought within a few inches of the floor will automatically assume the exact floor level, and, if brought out of line by stretching or shortening ropes, the platform will automatically resume the exact level with the floor. Formerly, it was difficult to bring the elevator platform to an exact level or to keep it there. When jarring weights, such as the front wheels of a loaded truck, entered upon the platform, it would stretch the ropes, or, if level when loaded, the ropes would contract and lift the platform after the first wheels of the truck were removed from the elevator, each time necessitating frequent shiftings of the controls by the operator. This switching backwards and forwards caused great loss of power and time as well as rapid deterioration of working parts.



(Courtesy of the Otis Elevator Co.)

FIG. 144.—The machine of the micro-drive, self-leveling elevator that has revolutionized warehouse construction. Front view No. 5 SS Type "O" W. G. T. machine, No. 35 A. C. motor, and No. 3 A. C. auxiliary motor.

The micro-drive-self-leveling elevator works on the following principle. To the main hoisting elevator machinery is attached a small motor that turns the drum at a very slow (one-tenth) speed. This auxiliary or micromotor is on a separate control system (Fig. 144). The main machinery is operated either by a push-button control outside, or a hand-switch control in the cab. When the elevator is brought within a few inches of the floor level and the main hoisting mechanism is switched off by the hand control or floor switch on the controller, contacts on the car and in the shaft above or below the exact level start the auxiliary micromotor and raise the solenoid brake that holds the main machinery in position when the current is shut off. This auxiliary motor then revolves the drum at a slow speed until the platform and the floor are

exactly opposite, when the contacts are broken and the elevator stops entirely. If a loaded truck comes upon the platform and the weight stretches the ropes more than a fraction of an inch below the floor level, the platform again makes a circuit throughout the contacts in the shaft, causing the microleveler to bring the platform back into position. In like manner, if loaded trucks are removed from the platform of the elevator and the ropes contract, the platform rises, making the upper floor contact, which causes the microleveler to lower the platform again to exact registration with the floor. This adjustment is so positive that a platform will automatically relevel in the time between the removal from the platform of the front wheels and the arrival of the rear wheels of a four-wheel tractor or trailer.

Central Control of the Elevator System.—In the great warehouses of the Army Supply Bases at Boston, South Brooklyn, Philadelphia, and New Orleans, all of the elevators are operated from one central control. Here the operator can observe the position of all the elevators in the building on an electric registry board, the elevator making a contact at each floor that causes a small lamp to burn on the board. Doors open automatically. When the car is loaded, the floor man pushes a button signaling to the starter. The cars are then dispatched by him through push-button control that also closes the doors. There is an auxiliary push-button control at each elevator door and in each car. This central control system is very fine if the warehouse is being worked to capacity. In the period since the high pressure of the war, however, when these great warehouses were only partly occupied, the time of one man at centralized control is not justified and the elevators are operated at the shaft. But if the warehouses are operating at normal efficient capacity, the microleveling automatic door opening and central dispatch will afford economies that will not only pay wages, but the entire installation will pay for itself within its normal life time out of its savings.

Ninety elevators of the ordinary type would require ninety regular and about twenty reserve operators, or one hundred and ten men. The eighteen one-story rise pier elevators require no operators, and each of the nine groups in which the high rise or warehouse elevators are arranged is handled entirely by a central dispatcher, as described.

From these figures it is clear that on the basis of the present operator wage of $1,600 per year, the annual saving is about $160,000, a very ample sinking fund yearly increment.

There is a further material saving in power consumption and wear and tear through the absolute elimination of operating abuse, as well as increased earning power from greater efficiency.

Large Platforms (Fig. 145).—The invention of the microleveling elevator brought with it the introduction of a very large platform to accommodate a number of tractor trailers. The idea is that the elevator

platform should be sufficiently large to carry a train of tractors and trailers at one time. This has led to platform dimensions of 9 feet 4 inches by 17 feet, 10,000 pounds capacity, and a speed of 150 feet a minute. These platforms are not large compared with, for instance, the four large platforms of the twelve Otis elevators in the Elbe Tunnel in Hamburg whose platforms with a lifting capacity of 22,000 pounds are capable of handling a large truck and three horses, or 140 people. For interior warehouse elevation, however, these large platforms with their microleveling device have been revolutionary because they permit the use of unit containers or loaded trailers without loading or unloading trailers, and the handling of the entire trains of tractors and trailers at one leveling. This being possible, goods will remain on a trailer truck for the entire time they are in movement within the warehouse, and often,

(*Courtesy of the Otis Elevator Co.*)

FIG. 145.—Part of a bank of large platform (17 feet by 9 feet, 4 inches) self-leveling freight elevators, Brooklyn Army Base.

even remain on the trucks until shipped out again. This means a reduction in handling, that is, in man power, but a heavier investment in equipment than in the old-type warehouses.

The Location of Elevators.—It is standard elevator practice to locate passenger or freight elevators in banks because of economy in installation, because of greater ease in operation, and primarily because of a better service. A person or a truck waiting for an elevator where there is a bank of six machines will have six times more frequent service than waiting for one single elevator in a single shaft to make its trips, as is the case when shafts are scattered around the building. But this advantage is not entirely without a disadvantage. The banking of the elevators at central points has led to the practice of placing these groups of units in the center of the building, or as in the case of the South Brooklyn Base or the Boston Base, as can be easily seen from the air views of the roofs, these banks are near the center line or somewhat to the rear of the

center line. The disadvantage of this location as compared with a location near the front of the building is apparent. A truck coming from the transit shed must half cross the building to the elevator shaft and then come back on the floor in which storage is to take place. The average of backhauls is therefore quite material. In the air views of the Norfolk Navy Supply Base at Hampton Roads, it will be seen that the elevators are near the front of the building. This is also the case in the projected drawings for the food-distributing warehouse. The object in locating elevators in the center of the building was to give low average haul and to move the point of congestion at the elevator doors some little distance from the point of congestion of the runways from the wharf to the warehouse. All of these points can be taken into consideration, and backhauling avoided, and still place the elevators in banks. Figs. 151, 165, 167, 173.

In high-priced property, where multistoried warehouses are an advantage, the construction in the future will, without doubt, tend towards increased height of the warehouses served by this modern elevator equipment.

The calculations of elevator requirements in the South Brooklyn Army Base, although on a much larger scale than will be encountered frequently, are of interest.

The Brooklyn Army Base embraces about 100 acres from landward line to pierhead, over 15 miles of railroad tracks, which include storage for 1,300 freight cars, and 8,000 feet of available string piece intended for loading simultaneously a dozen deep-draught ocean freight carriers.

There are two main warehouse buildings, "A" 200 by 980 feet, and "B" 240 by 980 feet; a mechanical and repair building; a four-story administration building, and three transfer sheds or pier houses, 150 by 1,350 feet each, which function in the transfer of freight to and from the water carriers.

The warehouse floors contain over 4,000,000 feet of floor space and the transfer sheds 1,250,000 feet, or a combined total of 116 acres. Including the transfer sheds for transient use, this affords actual storage space for about 15,000 carloads of goods.

Handling 15,000 carloads, or 300,000 to 400,000 tons of freight, on a 30-day turnover basis, requires the utmost possible conservation of time and effort.

There are ninety-six elevators in the plant, consisting of six passenger elevators in the administration building, seventy-two freight elevators in the warehouses, and eighteen on the piers.

The total number of freight elevators was based entirely upon the tonnage possibilities. It was considered that under the stress of war conditions twelve ships might be in berth for loading simultaneously. This would involve a maximum flow of goods from the warehouses,

via the elevators, of 1,500 tons per hour, or 25 tons per hour for each of the five hatches of each ship.

Only the utmost efficiency not only in the elevators themselves but in the method of control and operation would enable anything like a reasonable number of elevators to carry such a tonnage dependably.

Every feature, therefore, was most carefully considered, to the end that the plant has met the very heavy demands put upon it, not only in the way of total tonnage capacity, but in keeping the vertical flow of goods coordinated with the horizontal movement, and affording a service in which time lost *waiting* for cars is reduced to the minimum. This notwithstanding the fact that there are materially fewer elevators per unit of storage area than will be found in any other multistory warehouses which are at all fitted for the reasonably quick turnover of a considerable part of their contents.

Amount of Warehouse Space.—H. R. Geddes, an English expert in ports and freight-handling matters, told the author that the Antwerp authorities figured on a warehouse capacity of one and one-half times the cargo capacity of the port. However, at points which are to serve as reservoirs for particular harvests with an exceptionally high peak load during the movement of the season's product, this capacity may not be sufficient. Again we face a problem for the research activities of the serious scientific student. The thesis would be, What warehouse capacity is required at the chief ports for certain world commodities? Sugar at Havana, coffee at Santos, wool at Sydney, and grain at Odessa or at consignment markets such as London, Liverpool, and New York, would be among the cases studied.

In the calculation of space required at a port for marine terminal as well as general merchandising warehouses, the figures of the American Warehousemen's Association may be of considerable help, although due allowance must be made for the nature of a seasonal movement of any given commodity and port. These calculations are as follows:

Unoccupied Space in Per Cent of Total Floor Area

	Per Cent	
Aisle space (including space occupied by columns)	20 to 25	
Working space (around doors and platforms)	5 to 12	
Space permanently unoccupied		25 to 37
Waste space	0 to 8	
Idle space	0 to 40	
Space unoccupied at times		0 to 48
Total unoccupied space		25 to 85

In other words, the maximum and minimum percentages of occupancy are respectively 75 per cent and 15 per cent, the extremes of vacancy being 25 per cent to 85 per cent. The average is 45 per cent, but the committee of the American Warehousemen's Association believes that good business management in a standard warehouse would produce a little better than that, and so the 50 per cent figure has been used.

It will be seen that the effective warehouse floor area is about 50 per cent of any given general merchandise warehouse. It now remains to arrive at a calculation of the total port warehousing space necessary. A percentage of cargo loaded or outturned from the ships of the port that goes to warehouse storage may or may not be a guide in future calculations. Inasmuch as the port development of the United States has practically ignored the important function of the waterfront warehouse in the past, goods have moved to private warehouses, to public warehousing companies distributed about the port city, or, because of high rates for trucking and warehousing, have not moved at all. So far as it is known to date, no accurate calculation of the proportion of warehouse goods to total movement at the important ports of the world has been undertaken to form a guide on this point. Calculations that were made during the World War for the various Army Supply Bases are not applicable to general merchandising and transshipping conditions.

To arrive at an approximate figure of the total possible warehousing capacity required, several methods might be employed.

One might assume the total annual net tonnage of the ship movement of the port as a basis. Measurement cargo tonnage is two and one-half times the net registered ship tonnage. The cubical space necessary to accommodate all of the cargo at one time would be two and one-half times the total net tonnage movement. This is assuming that the average merchandise has a stowage factor of one, that is, 1 ton occupies 40 cubic feet. The warehouse space at the rate of 50 per cent occupied space would be twice this amount. This is on the basis of a turnover once a year, which, of course, is too slow. Three months average storage is a more reasonable basis. The seasonal fluctuations should be taken into account. It is necessary to accommodate the peak load of the principal commodity movement of the port, which may mean that the warehouses are largely empty during the light season. Typical of such commodities are cotton, wool, grain, coffee, and other similar seasonal movements. In this case, the net tonnage for the year would not give a true basis but the average for the busy season. Further, it must not be overlooked that the tonnage of ships moving in ballast should be deducted, and also partial loadings. Assuming a turnover every 6 months, without any accommodations for peak movements, we would have a gross warehouse capacity equal to $2\frac{1}{2}$ times the total annual net tonnage of the movement of the port.

Stowage factor $\times 2.5^{1} \times$ net reg. tonnage $\times 10^{(2)} \times 2^{(3)} \times \frac{1}{2}^{4} \times N^{(5)} =$ sq. ft. of warehouse space.

An example based on 1,000,000 net reg. tons $\frac{1 \times 2.5 \times 1{,}000{,}000 \times 10 \times 2 \times 1}{2} =$ 2,500,000 sq. ft.

Consideration from another angle would make our basis of warehouse space calculation the total berthing space in the port. Translate berth-

TABLE VI.—CHARACTERISTICS OF LARGE WAREHOUSES

Number of floors	Floor space, square feet; A storage			Number of freight elevators	Number of cars	Tailboard frontage lineal-feet	Remarks
	Shipping platform (B)	Space served by elevators (C)	Total storage space (D)				
8	44,800	3,894,000	3,894,000	72	93	1,824	U. S. Army (E)
8	37,670	1,344,000	1,573,500	24	90	960	U. S. Army (E)
6	19,800	512,000	565,500	7	28	90	U. S. Army (E)
6	F	600,000	600,000	10	F	101	Over l. c. l. freight house
3	20,860	561,100	561,100	15	32	F	Over l. c. l. freight house
7	F	357,100	357,100	7	F	F	Railroad warehouse
8	12,110	282,100	282,100	7	20	216	Private warehouse
4	22,700	438,300	438,300	6	24	356	Used by one tenant
8	F	184,400	184,400	6	F	F	Railroad warehouse
6	F	96,600	96,600	4	F	F	Railroad warehouse
8	7,370	201,800	223,900	4	8	100	Private warehouse
8	6,840	230,400	256,300	4	9	100	Private warehouse
6	50,400	1,261,400	1,421,000	30	100	1,000	Private warehouse
5	F	145,100	145,100	8	F	633	Over l. c. l. freight house
4	5,950	185,700	221,600	5	11	100	Used by one tenant

A—Floor area used is gross area, no deduction having been made in any case for columns, walls, elevators, checkers' booths, scales, aisles, etc.

B—Shipping platform space is the platform space adjacent to car siding used for shipping purposes.

C—Storage space does not include shipping platform space but does include all other space served by elevators.

D—Total storage space includes all warehouse space except shipping platform space.

E—The U. S. Army warehouses Numbers 1 and 2 are located on seaboard, and are served by both boat and rail.

F—Facilities of these warehouses are used by both freight house and warehouse and, therefore, exact amount used by warehouse is not obtainable.

[1] 2.5 cargo tons of 40 cu. ft. = 1 net reg. ton with a storage factor of 1. Therefore average stowage factor should be prefixed.

[2] 40 cu. ft. = 10 sq. ft. space occupied with 4′ tiering.

[3] Gross warehouse space 2 × effective space-

[4] Fraction of year of turnover: 6 mo. = ½ year.

[5] Fraction of total traffic passing through warehouse.

ing space into cargo tons capacity of the ships at 40 cubic feet per ton. In the total warehouse floor area, there is 50 per cent active storage space. Assume a warehouse turnover of 90 days and a ship turnaround of 10 days or three ships a month. If one may assume from experience that half of all the freight received at the port passes through the warehouses and that the effective capacity is 50 per cent of the total area, we would arrive at an effective warehouse capacity requirement of one and one-half times the total berthing capacity of the port, which is the Antwerp figure. This is the effective capacity of the warehouses. The total floor area would therefore be three times the total cargo capacity, weight and measure, of the wharves, assuming that all ships are loaded with an average stowage factor of one, full and down. But once a month warehouse turnover is too quick and one and one-half times berth capacity is therefore low in proportion. Assuming the formula above, the terminal. capacity in net registered tons of the ships that can be accommodated at any one time times ship turnaround will work out in a similar manner. The result is the same.

There are too many variables in this quadratic equation to solve it accurately except by careful analysis of each one of the factors, one at a time. Some notable examples of warehouse proportions may be helpfu (Tables VI and VII).

TABLE VII.—RELATION OF ELEVATORS TO WAREHOUSE FLOOR AREA[1]

Floor area per elevator, square feet		Number of tenants	Size of elevator in capacity of 3 by 6 foot trucks	Floor area per elevator, square feet		Number of tenants	Size of elevator in capacity of 3 by 6 foot trucks
Present	Recommended by operating officials			Present	Recommended by operating officials		
Storage warehouses with slow turnover				Warehouses with moderately rapid turnover			
60,000	.....	Many	3	37,406	.....	Many	4
50,450	.....	General storage	2	51,014	39,680	Many	2
				40,300	.....	Many	3
57,600	.....	General storage	2	73,050	.....	One	3
				30,733	.....	Many	3
	U. S. Army Warehouses.			24,150	32,220	Many	1
54,084	.....	One	4	42,046	.....	Many	3
56,000	.....	One	4	37,140	.....	One	2
73,143	56,889	One	3				

[1] "Analysis of Design Factors for Warehouse Facilities," unit values that insure adequate elevator service, tail-board space, trackage and shipping area for given floor space, *Abstract of subcommittee Report of Committee on Yards and Terminals, American Railway Engineering Association, Eng. News-Record*, May 4, 1922.

CHAPTER XII

THE PORT TERMINAL WAREHOUSE (*Continued*)

SHAPE AND LOCATION OF WAREHOUSES

The Shape of the Warehouse.—The shape of the warehouse is of considerable importance both as to cost of construction and as to arrangement of the various elements entering into warehouse operations. With a view to reduction in the cost of construction, whether the warehouse

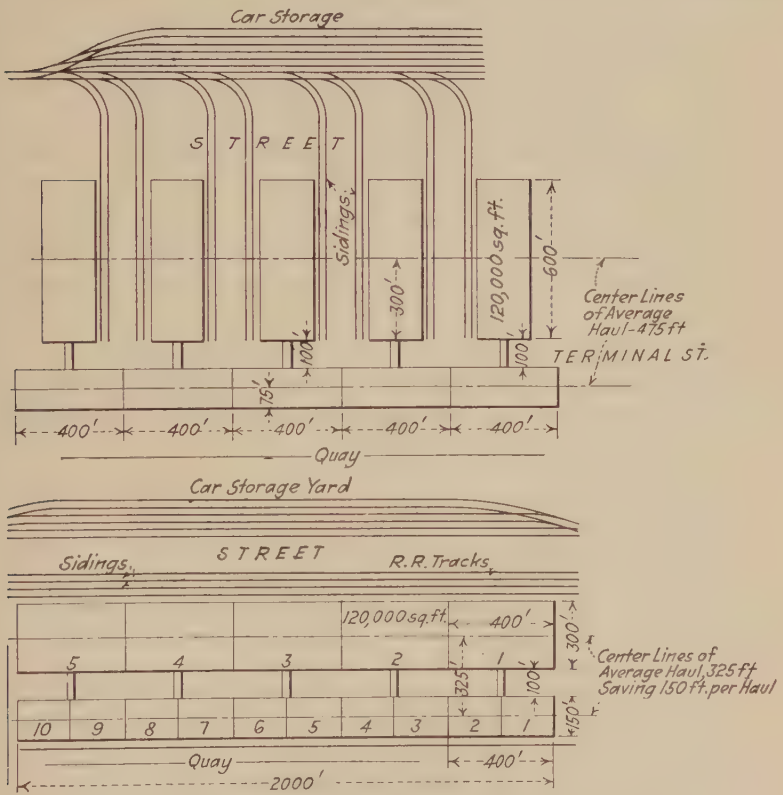


FIG. 146.—Relative advantages of squares and parallelograms.

floor plan is square or oblong seems at first unimportant. It must, however, be borne in mind that the parallelogram with the greatest area is a square and the parallelepipedon with the greatest volume is a cube. Therefore, the closer a warehouse approaches a square floor plan, the greater area obtainable for the materials of construction and foundations.

There are, however, even more important relationships to be established, such as the utilization of the ground, the accessibility for drays and trucks, and the distance for hand trucking or power trucking about the property. These relationships will be viewed from various angles as the discussion of the port terminal warehouse problem proceeds.

The example of the compactness made possible by parallel warehouses with the compartments approaching a square floor area is set forth in Fig. 146. In this case the 2,000-foot quay wharf with 150-foot wide head house giving berthage to four 500-foot ships, is taken as a basis and is identical in both sketches. In the first sketch, the warehouses are constructed oblong, at right angles with the quay front, with stub end tracks from the car-storage yard. The terminal street in both cases is taken as 100 feet spanned by bridges. Each warehouse is 600 by 200 feet, having an outside periphery of 1,600 feet to give an area of 120,000 square feet on each floor. The first warehouse may be illustrated by the air view of the Army Base in New Orleans (Fig. 173). The second example has also five warehouse units in one large building, each unit of 120,000 square feet area on one floor. The two end compartments— # 5 and 1 take outside walls 400 + 300 + 400 = 1,100 feet long and inside or dividing walls 300 feet. The three interior compartments have only 800-foot outside walls and 600-foot inside fire walls shared with next section. In other words, for the same floor area each of the five compartments have 200 lineal feet less of wall, if standing alone.

But for the terminal II on squares the saving of exposed wall surface totals 3,200 feet for the terminal. The total saving in all wall measurement is 2,200 feet but, in addition to this saving of the remaining walls 1,200 feet is inside wall and therefore less expensive:

I	II	Saving in Walls
Area $5 \times 600' \times 200' = 600{,}000^2$	$5 \times 300' \times 400 = 600{,}000^2$	
Total walls all with double partitions $5 \times (600 + 600 + 200 + 200 = 1{,}600')8{,}000'$	$5 \times (300' + 300 + 400 + 400 = 1{,}400') = 7{,}000$	$- 1{,}000'$
Total walls with single partitions $5 \times (600 + 600 + 200 + 200 = 1{,}600')8{,}000'$	Outside / Inside #5 1,100′ + 300′ #1 1,100′ + 300′ #4 800′ + 300′ #2 800′ + 300′ #3 800′ +	
	$5{,}600' + 1{,}200' = 6{,}800'$	$- 2{,}200'$ (all walls) $- 3{,}400$ (outside walls)

There are several other advantages in this utilization of the site such as the greater concentration of railway tracks, although there is some

loss in the length of the loading platform. Even so there is sufficient car-loading platform for the business of the warehouse. The most important advantage of the second form of layout is the greatly reduced trucking distances that are reflected instantly in the cost of moving merchandise about the terminal, *i.e.*, "labor in and out." In the first case, the average haul from the center line of the transit shed to the center line of the warehouses is 475 feet as against 325 feet in the second layout, an average saving of 150 feet every time a hand truck or motor-trailer truck makes a trip from transit shed to warehouse, 300 feet each round trip.

The example illustrating the advantage of the square layout compared with the oblong layout will be seen in the air view of the Boston Army Base (Fig. 165).

Coordinations to be Established in a Port Warehouse Terminal.—Having considered the economy of construction involved in the principle of the square floor plan as against the parallelogram or oblong, there now remains to be studied critically the various relationships in the question of trucking distance and rail tracks.

These relationships involve the warehouse, and sometimes open-storage space, in connection with four other variables. First, there is the ship at the wharf. Inasmuch as the transit shed is serving the ship, coordination exists between the transit shed and the warehouse. Second, there are railroad tracks; third, drays and motor trucks; fourth, harbor lighters. A critical examination of the relationships of these four elements with the warehouse will go far to decide which layout will give the most economical waterfront storage both in construction and operation.

The Ship (Transit Sheds).—Contrary to pretty pictures showing ships discharging directly into warehouses, the growth in the size of ships

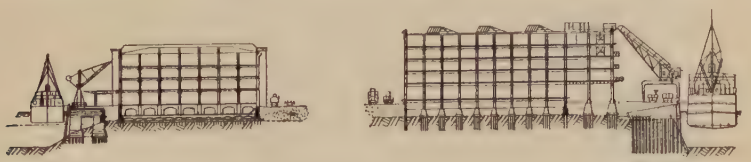


FIG. 147.—Rotterdam warehouses with exterior elevation by wharf cranes on the waterside and by cornice hoists on the land side. Type of quayside warehouse with transit shed ground floor.

and the growth in liner traffic handling diversified cargoes and the decline of charters (solid cargoes in tramps) have rendered obsolete such direct loading and discharge except in rare cases where large merchants or manufacturers handle whole cargoes into their own warehouse. The first public warehouse at Hamburg, about 1771, at the tip of the quay pier between Sandtorhafen and Grasbrokhafen was built with the idea of direct transfer between ship and warehouse. It was soon found that as ships grew in size and diversity of cargo, the cargo must be discharged into a transit shed where it could be spread out and sorted according to

marks and consignees. This warehouse was found to be impractical for direct transfer between ship's hold and warehouse. Hence, the increased importance of the transit shed and the infrequent direct movement to warehouse floor direct from the ocean ship. The water-side warehouse has retained its value because of the direct transfer between small harbor and river lighters, and barges. Figure 147 shows a great tobacco warehouse at Rotterdam. There is transit-shed space reserved on the ground floor. Cunningham rules against this type as tending to congest car and cart loading platforms that must serve both transit and warehouse freight.

Railroad Tracks.—The location of tracks for warehouses follows very much the same principle as the location of the sidings on the wharf and back of the transit shed. There are the same advantages and disadvantages of the spur or dead-end track, the same advantages and disadvantages of the through or loop track. Inasmuch as the warehouse tracks may be of great importance to the transit shed as well as to the warehouses, their study from the point of view of trucking distance is very important (Table V). In large cities with an intensive use of the land and with the increased use of electric switching locomotives, rail spur tracks are inside of the building. This is true of the London warehouse, the new Pennsylvania warehouse in Chicago, warehouse *B* at the Army Supply Base in South Brooklyn, and in many other warehouse designs shown in the illustrations.

Drays and Motor Trucks.—There is constant conflict between the railways and the drayways. In the warehouses arranged at right angles with the waterfront at Charleston, Newark, Norfolk, New Orleans, the right-angle or finger warehouses have depressed railroads at one side and drayways at the other, alternating rails and drayways. However, all of these examples are extensive developments with regard to the ground area covered. In the intensive ground-area development of larger cities, the question of drays is even a more difficult problem. All warehouses, in large cities, whether of waterfront terminal or private domestic nature, have come to adopt an inside design of tail board platform with saw-tooth, 45-degree angle, parking. All railroad tracks are channels set flush in the pavement, permitting motor trucks and drays to pass over them to reach their own tail-board platforms.

Lighters.—Lighter connection to warehouses has been largely overlooked in the United States. The harbor lighter is the principal means of transportation between warehouse and ship, transit shed, river barge, and private merchant's warehouses in important and successful harbors such as Hamburg, Rotterdam, Amsterdam, and London. There is no harbor in the world that needs it quite so much as New York. Therefore, it is necessary to add to the other three warehouse design difficulties the fourth difficulty of lighter communication.

The economy and flexibility of the lighter in moving goods between the warehouse and other elements in the harbor were demonstrated by the practice of centuries at Hamburg where the warehouses were built directly on the numerous canals necessary to drain the marshes in which

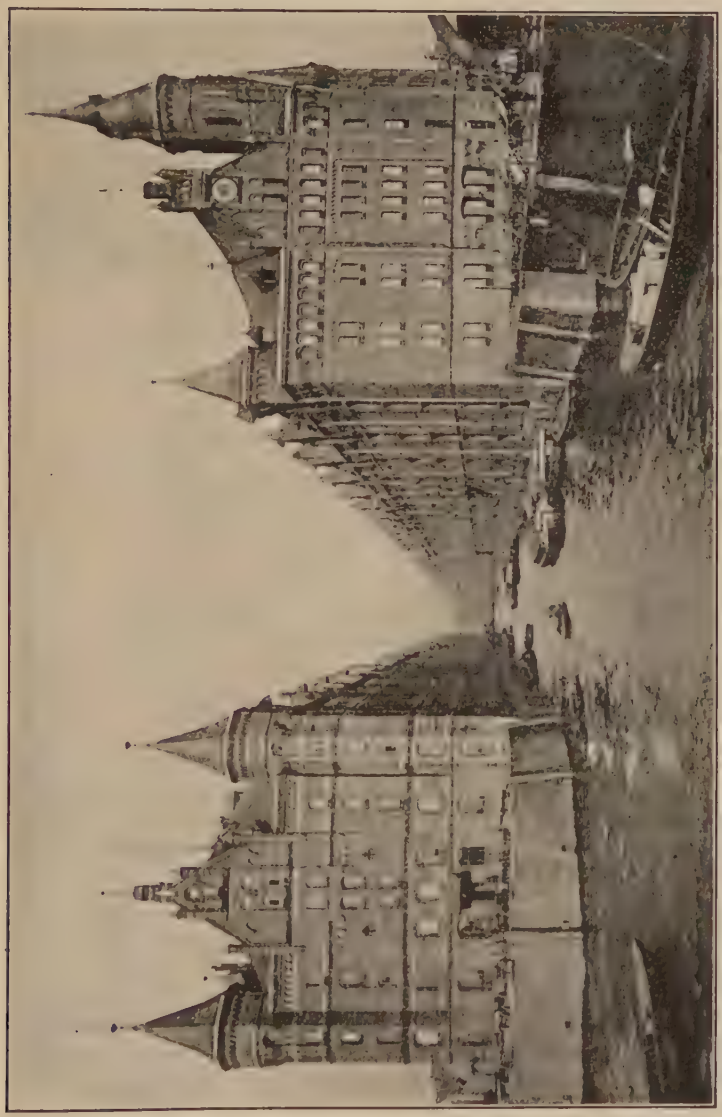


FIG. 148.—Warehouse group of the Free Port with canal constructed to furnish lighter and barge connection to one side of the rows of warehouses.

Hamburg was built. When the free port was laid out between 1882 and 1888, the practice that had grown up originally by accident was continued by design. A section of the town between the Binnenhafen and the Sandtorhafen was raised, and a canal excavated directly through

the middle of this area upon which the warehouses were built (Fig. 148). The new Speicherstadt thereby had canal connection on one side and dray and rail platforms on the land side. The economy of the lighter service is so great at Hamburg that a private warehouse situated without water connection, and not on one of the many canals, is considered undesirable and brings a much less rent. When the writer was looking for a warehouse for his company in Hamburg, not being thoroughly conversant with this method of warehouse connection, he was puzzled

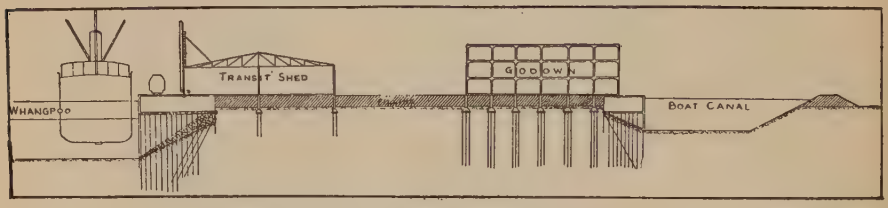
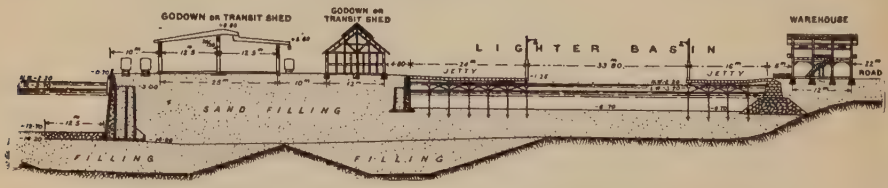


FIG. 149.—Quay and Parallel warehouse type with lighter connection for the warehouse. Commercial wharf and dock section, Shanghai, China.

for some time by the fact that the agent invariably pointed out that a property had or did not have water connection which accounted for the seemingly high or low rental rate per square meter. It was not until after considerable explanation that *Wasseranschluss* assumed its proper connotation, neither city-water mains nor sewers, but lighter canals.

The importance of the small boat in the interior transportation of China is reflected in the recent drawings for the Commercial Wharf of the Whang Poo Conservancy Board for the Port of Shanghai, China



(*Dock and Harbour Authority.*)

FIG. 150.—Lighter basin provided in the recent harbor works of the Port of Macassar, Dutch East Indies. H. W. van der Voost, Chairman, D. B. Talma, Chief Engineer.

(Fig. 149). In this case, the go-down or warehouse is situated to the rear of the transit shed across a marginal street but on the other side is provided a boat canal and wharf for this interior communication by lighter and small boat, the Sampan trade. Likewise, at Macassar, Dutch East Indies, a similar layout has been followed (Fig. 150).

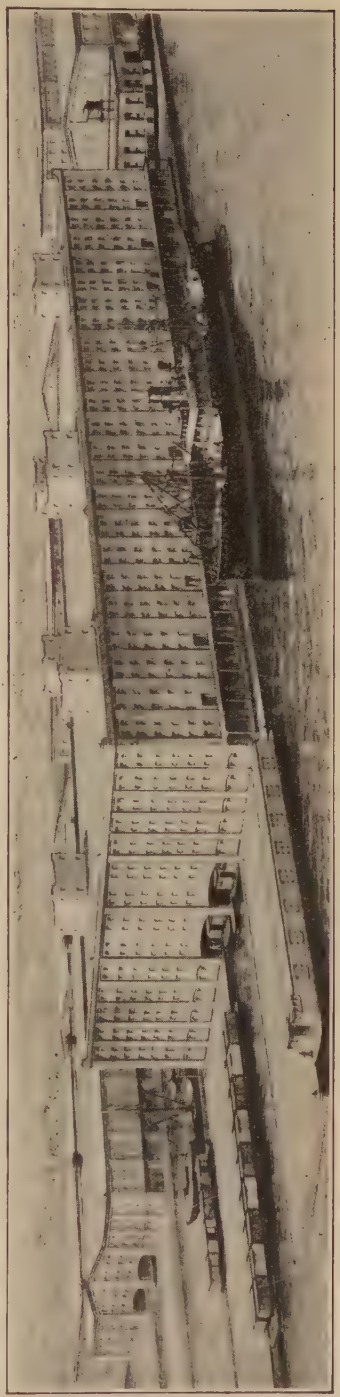
It may be argued that China and Celebes have few railroads, and that this system at Hamburg grew up before the introduction of steam rail transportation, and, therefore, that this lighter connection is a relic of

the past. The usefulness of lighter connection with warehouses is not made any less because of the introduction of the railroad. All these transportation movements are necessary in a modern port. Otherwise, why would the most modern port works incorporate this feature?

This fact is given proper consideration in a recent design, by William T. Donnelly, of a port food terminal for storage and distribution of perishables by water and land. It has already been noted that railroad cars and drayways have been taken inside of the large modern warehouse building. Mr. Donnelly has gone a step farther and brought also the lighter canal inside of the building to permit the handling of refrigerated products between car or refrigerated barge and cold storage without changing temperature (Fig. 151).

Pier and Slip Layout with Lighter Canal to Warehouses.[1]—The writer proposed several layouts of waterfront terminal warehouses with lighter connection.

Figure 152 is a suggested pier and slip development. The slips were made somewhat wider than usual to accommodate a canal for lighters leading from the foot of the slip into the upland, alternating with the street leading to the pier. The bulkhead area was occupied by a transit-storage warehouse serving the pier, the ground floor being used as a "farm," also as an arcaded driveway onto the pier, and for railroad car-loading platforms. The upland was occupied by the ware-



(*William T. Donnelly, Engineer.*)

FIG. 151.—Cold storage warehouse for land and water connection with lighter canal within the building.

[1] In a paper before the American Association of Port Authorities, at their Chicago Convention, 1920.

houses for general merchandising to be owned or leased by business firms operating them for their own use or in the merchandising business. As the canals for the lighters and the streets for the drays alternate, the rail tracks with frequent crossovers pass along the center of the first floor of the warehouse and into the bulkhead storage warehouse. They are provided with a switching track and frequent crossovers. With this lay-out, a merchant could ship or receive goods by lighter, by railroad, or by truck as the occasion demanded. The appearance of such a lighter canal is indicated by the photograph of the Hamburg prototype (Fig. 148).

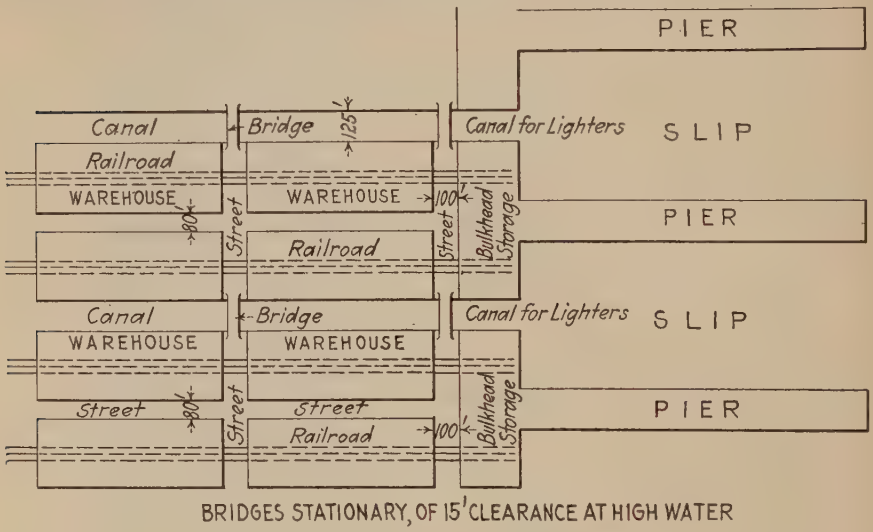


Fig. 152.—Warehouses with lighter canals.

It may be pointed out here that the *transit-storage* warehouse on the bulkhead may serve the pier and the steamship line occupying the pier by affording the pier surplus storage for cargo arriving too far in advance of the sailing of the vessel or held over the 48-hour period and ordered to the warehouse. For this purpose, the bulkhead storage warehouse is of great importance, but such a location is of minor imporsance to a business firm receiving its merchandise for storage until it is told and reshipped, because a merchant is not tied to one pier and one line of ships using that pier, but must have connection with every railroad, every other warehouse, and every ship in the harbor. He may receive part of his materials in solid car lots that are carried out into his warehouse, and, at a later time, he may sell a consignment of goods to a department store in the city and remove them there by motor truck over the city streets, or he may make delivery at some city reached by coastwise steamer and will want to lighter his goods from the water side of his warehouse to such a ship. For this reason, a modern merchandising warehouse must have lighter connection.

In such a warehouse area, the streets should be raised to 15 feet above high water in order that the bridges may be fixed and not interfere with

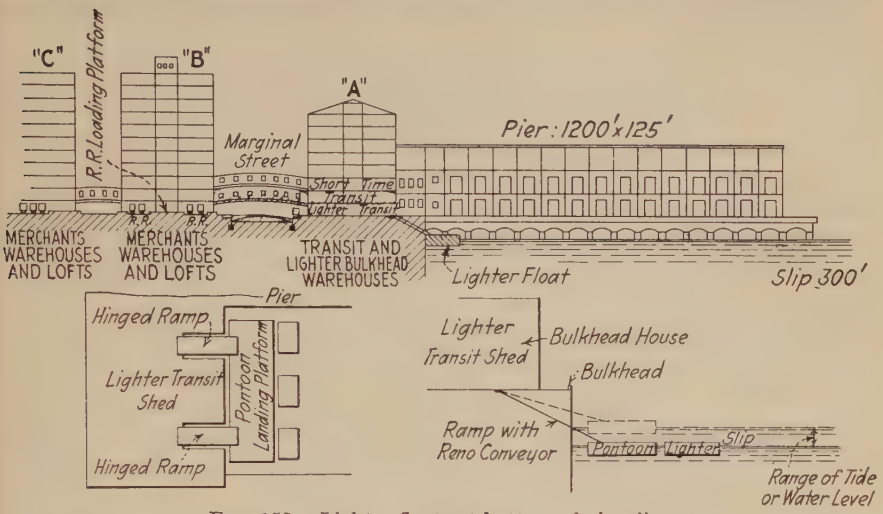
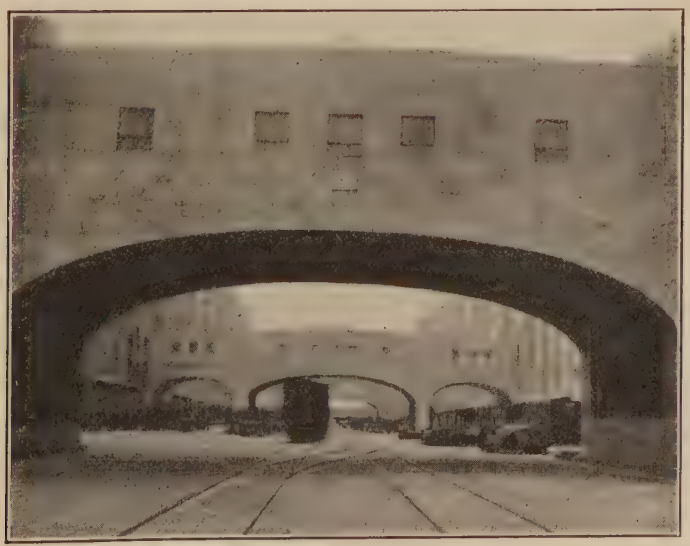


FIG. 153.—Lighter floats at bottom of pier slips.

street traffic. Inasmuch as the future lighter for this type of work is without masts and drawn by motor towboats without funnels, 15-foot



(Photograph by the author.)

FIG. 154.—Connecting bridges of waterfront warehouses. Brooklyn Army Base, Cass Gilbert, Architect. Iron and cement may have graceful lines.

clearances are ample. This may make a basement wharf possible for the handling of lighters on the floor below that occupied by the team

and track shipping. This would make unnecessary cornice hoists in the modern warehouse with interior elevation, as lighter freight would be landed and moved to elevators. This bridge elevation and basement wharf would accommodate New York Barge Canal Barges.

Lighter Connection at Bottom of Pier Slip.—In the case of high or rocky land, as at Manhattan Island, making the cost of a lighter canal prohibitive, another solution is suggested in Fig. 153. This consists of a pontoon landing platform with hinged ramps at the foot of the slip to afford transfer from lighter to a lighter transit shed forming the main floor of the bulkhead warehouse *A* and the usual trucking by tractors and trailers or platform lift and electric trucks to the merchants' floor in merchants' warehouses *B* and *C*. If a Cass Gilbert is the architect, the bridges across the streets, albeit of iron and cement, may have the beauty of line of a Bridge of Sighs, as in the case of the Brooklyn Army Base (Fig. 154).

In either case (Fig. 152 or Fig. 153), the merchant occupying a waterfront warehouse has complete flexibility of movement by lighter as well as by rail and by dray to any point in the harbor.

TYPES OF QUAY-SIDE WAREHOUSES

Quay-side Warehouse. Type 1.—It was stated that a very small proportion of cargo can be transferred between ship and warehouse without the intervening transit shed. However, if the ground floor, and, perhaps even the second story, are used as a transit shed, and if the nature of the subsoil is such as to permit foundations that will carry high superstructures, it is possible to build quay-side warehouses similar to those in Rotterdam (Fig. 147). Inasmuch as lighters may come alongside after a ship has left the berth (as they now do at the transit sheds at Hamburg and elsewhere) no lighter canal is necessary. Such a canal would, however, make possible a more intensive use of the terminal.

The criticism of the quay-side warehouse has been directed primarily against the fact that in most harbor areas it is difficult to obtain a footing in deep water for structures of the magnitude and weight of such a building.

The China Basin Terminal at San Francisco is the most recent American example of the multiple-storied, transit-storage warehouse at ship side (Fig. 155). This is a large project. The terminal building will be 812 feet long and six stories high, the main structure being 100 feet in width for the upper four floors. The wharf apron is 22 feet in width at the ground or transit-shed floor. The second floor is set back 13 feet to allow a landing platform on the second floor, while the third story is set back 10 feet, allowing another 10-foot landing platform from which cornice hoists

handle cargo to the other three floors. Expressed in another way, the main structure is set back 45 feet and is 100 feet in width, while the ground and second floors, which are used as transit sheds, have extensions of 23 feet and 10 feet onto the wharf apron. Details are visible from the

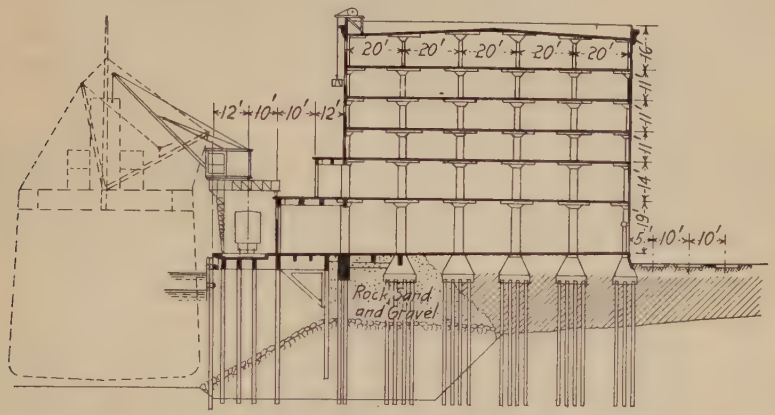


FIG. 155.—Elevations and section of proposed seawall, fill and six-story warehouse on the China Basin section of San Francisco's waterfront. Since this drawing the actual construction (two floors, summer 1925) has bridged over the second floor across the three inshore tracks and a saw-tooth tailboard platform at 2d floor level provided. F. W. White, Chief Engineer.

drawing. The floor heights are 19 feet, 14 feet, three at 11 feet, and the top floor 16 feet.

Since originally designed, a drayway has been included on the second floor above the three railroad tracks.

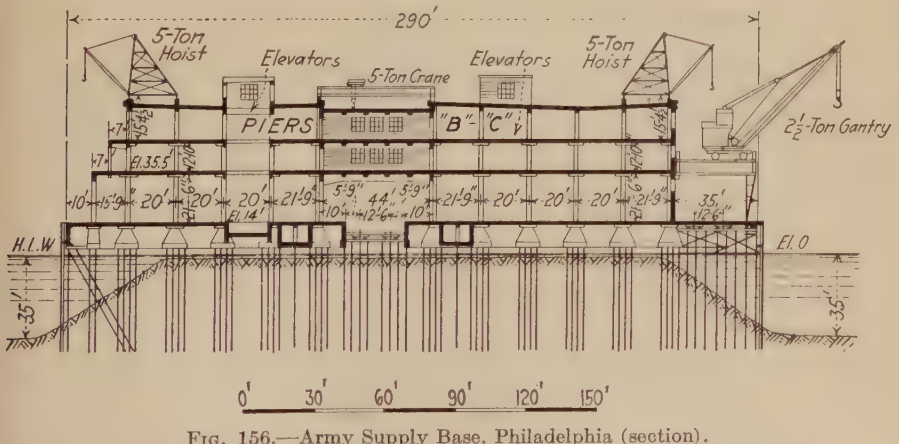


FIG. 156.—Army Supply Base, Philadelphia (section).

In this case, there seems to be no doubt whatsoever of the ability to carry structures of this weight at the edge of deep water. It will be noted that the warehouse is set back 45 feet from the water's edge and thoroughly anchored.

The question of the multiple-storied transit shed is almost identical with that of the quay-side warehouse. The function of this type of multiple-storied pier shed has been discussed under transit sheds, but due to the similarity of the problem of construction, the Army Supply Base at Philadelphia in plan and section is shown herewith (Fig. 156).

The Warehouse Located at the Rear of the Transit Shed. Type 2.—At Bremen (Fig. 157), Stettin, Gothenburg, and elsewhere, the warehouse

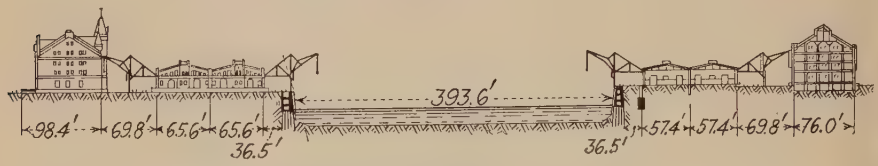


FIG. 157.—Cross-section of Bremen basin showing arrangement of cranes, sheds, and warehouses.

has been located directly back of the transit sheds across a marginal driveway. Goods intended for the warehouse are trucked across the shed deck to the rear where the crane picks them up and sets them on the floor of the warehouse where they are to go. The most modern example is at Gothenburg, Sweden (Fig. 158). Los Angeles shows a similar layout without cranes (Fig. 159). The fact that this warehouse has not been a commercial success is not entirely due to design but is due largely to its remote location. The chief fault is in the lack of trucking connection between transit shed and warehouse separated by roadway and rails.

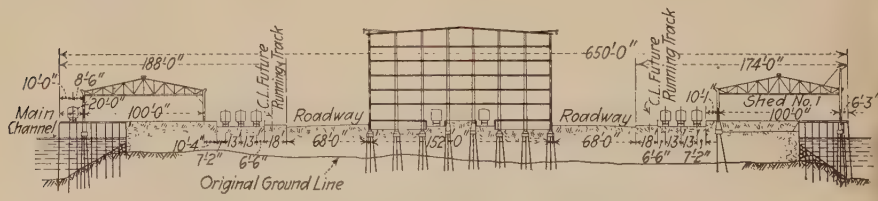


FIG. 159.—Wide quay-pier with parallel center-line warehouse, Los Angeles, 1914. Right-hand side only has been completed.

Faults of This Layout.—This seems very good in theory, but let us look at the situation more closely. Suppose that a merchant keeps his stock all together in a warehouse *A* and a ship with a consignment for him docks at wharf *F*, a mile down the quay. It will be necessary to cart the consignment a mile along the waterfront. The warehouse might as well be a mile inland. The carting is the very thing which it was sought to avoid by locating the warehouses directly behind the transit shed.

Trucking distances become important as soon as the warehouse is moved to a point away from the transit shed. This has been already

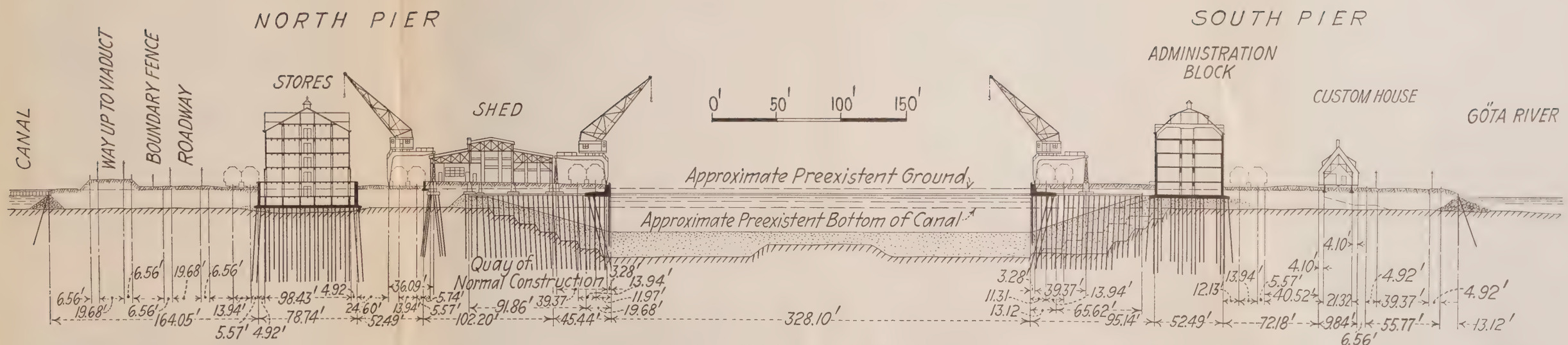


FIG. 158A.—Cross-section of free port of Gothenburg. Section of basin, quays and warehouses.

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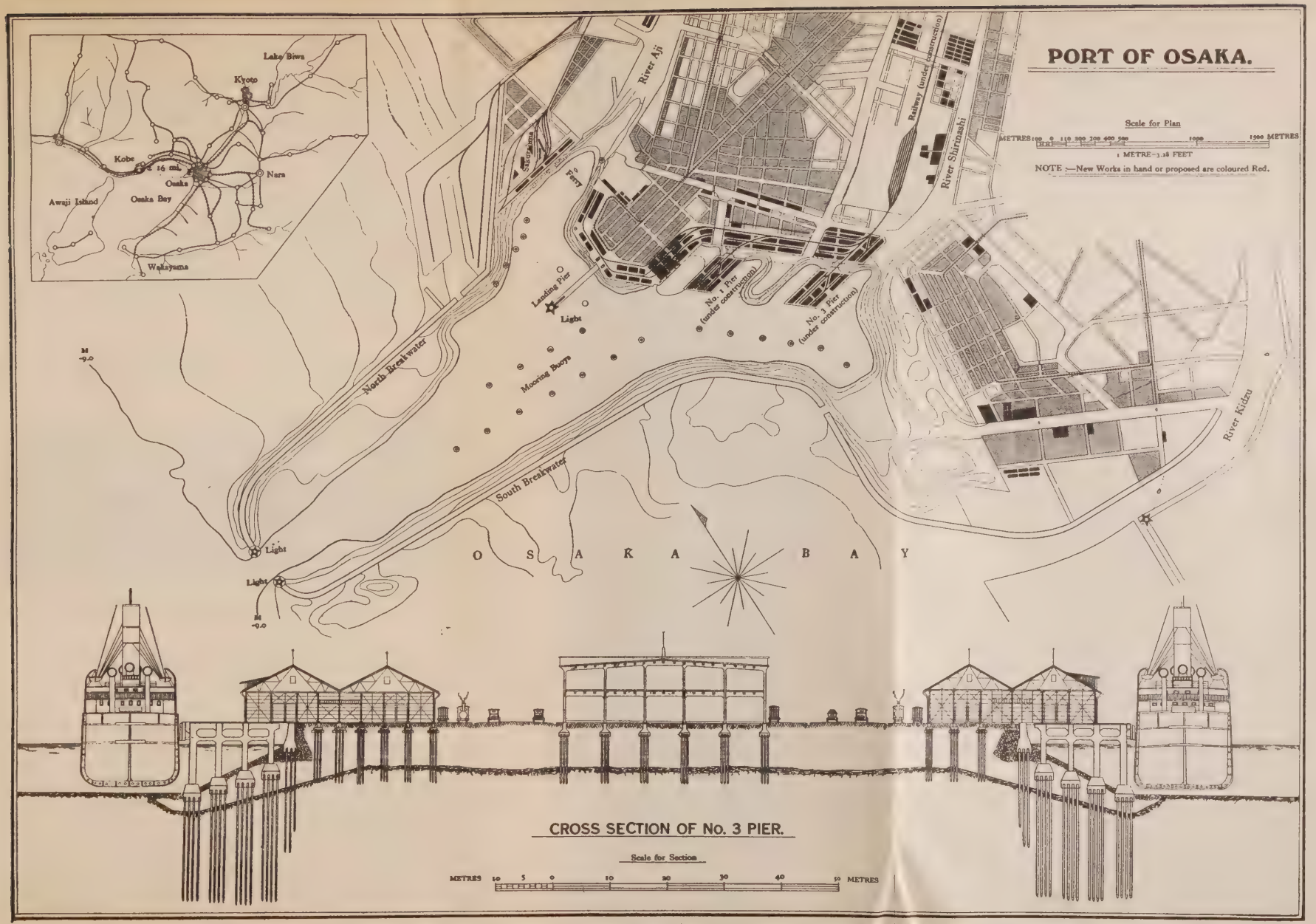

FIG. 158*B*.

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alluded to and is one of the factors that will constantly arise in valuating a terminal layout. If the quay-side warehouse, such as at Rotterdam or China Basin, has sufficient floor area on the ground floor left for use as a transit shed, the remainder of the structure is naturally within short trucking distance.

If the warehouse is moved to the rear of the transit shed, the trucking distances increase and the prime object in the warehouse design will be to reduce this to a minimum. Table VIII of the relative trucking distances of several important terminal warehouses gives the comparative advantages of these several cases and at the same time indicates the wide spread between the various types when studied from this point of view.

Study Table VIII Carefully.—It discloses very important relationships between ship, transit shed and warehouse from the viewpoint of future operating costs. To our knowledge this is the first analysis of this situation in any literature.

Piers and Bulkhead Warehouse. Type 3.—Although not located directly at the bulkhead, which could easily be done, the proposed

FIG. 160.—Bulkhead warehouse and pier system. Note "Farm" on ground floor of warehouse area, also viaduct over belt-line tracks. Tower for offices.

Admiral Line Terminal at Seattle (Fig. 160) is an example of the usual, long, narrow pier development with double-deck transit sheds and the warehouse across the shore end of the pier. In this case, the bulkhead warehouse is built above the farm with the railroad tracks serving the piers, drayways and other traffic passing under the warehouse proper. The warehouse consists of five stories above the main floor, the central office pier (middle tower) rising ten stories above the first ground floor, and five stories used for warehouses. There is a similarity of appearance with the Market Street Ferry, San Francisco. To avoid the danger and confusion of the belt-line tracks at grade, a viaduct reaches the second floor of the warehouse to afford easy access for trucks, vehicles, and pedestrians. This case offers an intensively developed bulkhead warehouse plan with the warehouse sections approaching the compact cubical form. There is freedom of all vehicular movement on the ground floor and part

TABLE VIII.—INBOUND TRUCKING DISTANCES FROM WHARF TO WAREHOUSE

Location Army Base at Examples from Berth	Sling to shed		Elevation			Across bridge or street, feet	Warehouse A				Bridge or street, feet	Warehouse B			Total distances, feet
								Elevators					Elevation		
	Feet across wharf apron	Within shed, feet	To elevators, feet	Floors up	From elevators, feet		Main floor, feet	To elevators, feet	From elevators, feet	No. floors		Main floor, feet	To elevators, feet	From elevators, feet	
Boston, Mass.															
I. Opposite any section.	34	170	130	1	50	86	thru → 60	63	150	8	none	.....	.....	....	683
II. Opposite any section.	34	thru →	50	1	50	86	....	....	....	....	none	.....	.....	....	280
III. Opposite any section.	34	thru →	50	1	50	86	thru →	63	75	8	none	.....	.....	....	324
Brooklyn, N. Y.															
I. Pier 3.	5½	60	100	1	1,220	285	thru →	150	200	8	155	→	280	150	A.2,020 B.2,605
II. Pier 3.	5½	thru →	30	1	120	285	100	....	....	....	155	60	.....	....	A. 530 B. 745
III. Pier 3.	5½	thru →	50	1	650	285	thru →	85	100	8	155	→	60 250	100	A.1,175 B.1,740
Charleston, S. C.															
I. Wharves 1 and 2.	40	190	....	..	.....	....	2,710	....	....	....	....	.....	.....	....	2,940
II. Wharves 3 and 4.	40	150	....	..	.....	....	50 80	....	....	....	....	.....	.....	....	320
III. Wharves 3 and 4.	40	170	....	..	.....	....	600 80	....	....	....	....	.....	.....	....	790
Newark															
I. House 1 and 2.	.....	350	....	..	.....	....	(Warehouse 1) 1,220 east section	....	....	....	....	(to warehouse) 3,300	.....	....	9) A.1,570 B.4,870
II. House 1 and 2.	.....	90	....	..	.....	....	150 first section	....	....	....	....	.....	.....	....	240
III. House 1 and 2.	.....	125	....	..	.....	....	635 middle section	....	....	....	....	(to warehouse) 1,590	.....	....	5 middle 1,830
New Orleans															
I. At left to warehouse 1 last compartment.	20	230 (diagonal)	300	1	1,300	430	thru →	300	300	....	....	.....	.....	....	2,880
II. Opposite wharf 2.	20	140 (straight)	70	1	100	410	100 (middle section)	....	....	....	....	.....	.....	....	840
III. In middle of wharf to warehouse 2, mean average haul.	20	185 average	185	1	280	420	thru →	300	150	....	....	.....	.....	....	1,530
Norfolk, Va.															
I. Outer end Pier No. 2 south side to warehouse 8.	36	100 1,280	....	..	.....	75	1,396 1,680 160	....	....	none	....	.....	.....	....	4,700
II. End north side Pier No. 2.	36	50 100	....	..	.....	75	3,236	....	....	none	....	.....	.....	....	261
III. Middle of pier to middle of warehouse 2 or 7.	36	80 640	....	..	.....	75	450 700 80 1,230	....	....	....	....	.....	.....	....	2,061
China Basin, San Francisco	Crane transfer to 2d story platform	Gable hoists	....	4	100	....	.....	.....	.....	.....	....	.....	.....	....	100
Quayside warehouse.			....	4	100										
(Calif. State Port)			....	4	50	....	.....	.....	.....	.....	....	.....	.....	....	50

I. Maximum distance to farthest corner measured from farthest hatch.
II. Minimum distance from nearest hatch to nearest practical place of rest.
III. Average distance of through travel to warehouse based on center lines of structures.

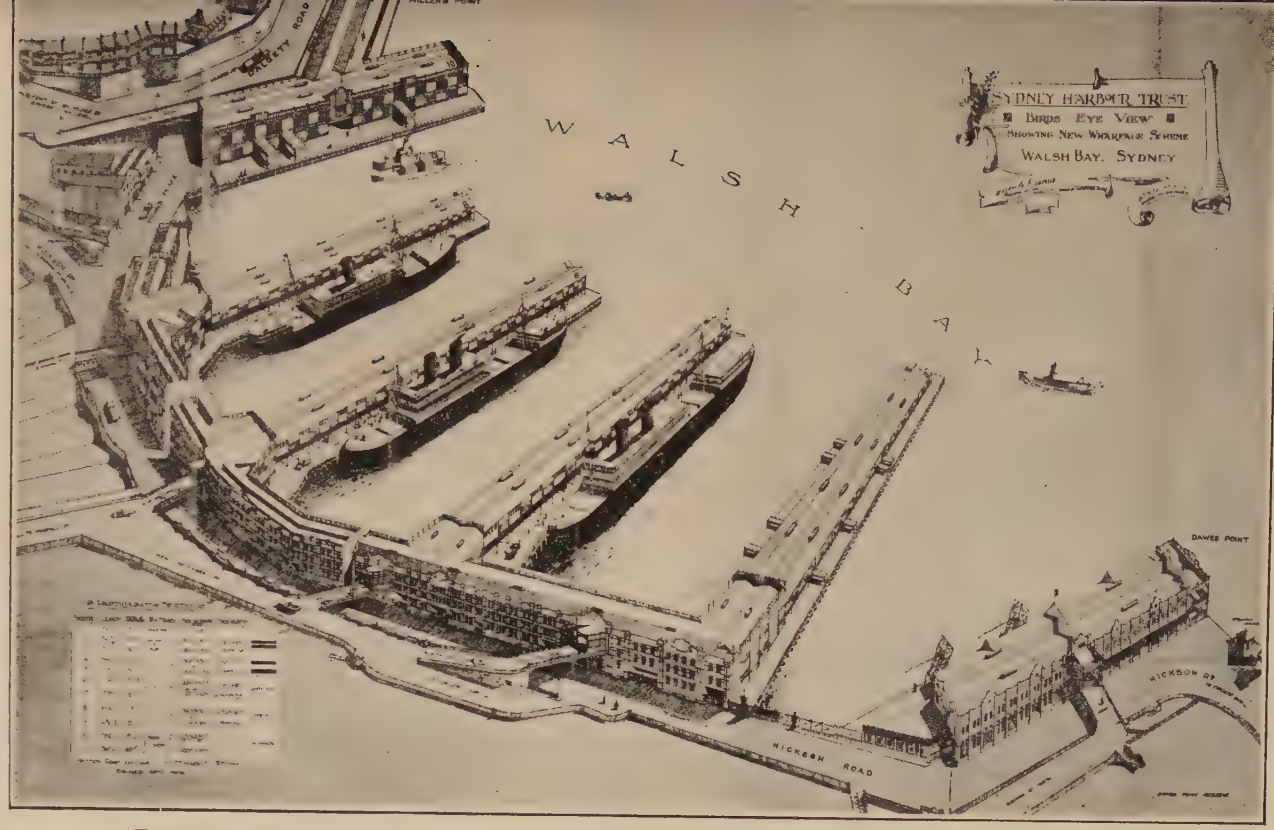


FIG. 161.—Sydney Harbour Trust. Bird's-eye view showing new wharfage scheme, Walsh Bay, Sydney. Piers with bulkhead warehouses.

of the second floor plus an excellent development for offices, and, for that matter, passenger accommodations if desired. If the piers and bulkhead warehouse were joined, there would be perfect interrelationship of all elements (see small plan).

Very similar to this is the Walsh Bay Terminal at Sydney, Australia (Fig. 161).

Pier and Bulkhead Warehouses at Islay Creek Section, San Francisco.—This proposed development, shown in sections in Fig. 162, is a typical double-pier layout with piers 235 by 1,500 feet and a 350-foot slip. A farm or open space is left at the entrance to the piers but facing these slips; four-storied warehouses are set back 65 feet across a bulkhead apron wharf from the actual bulkhead line. Such warehouses would serve both the purpose of transit storage and merchandising, as the warehouse wharf would connect with the harbor lighter traffic at the bottom of the slip. It is also served by tracks with the dray tail-board platforms

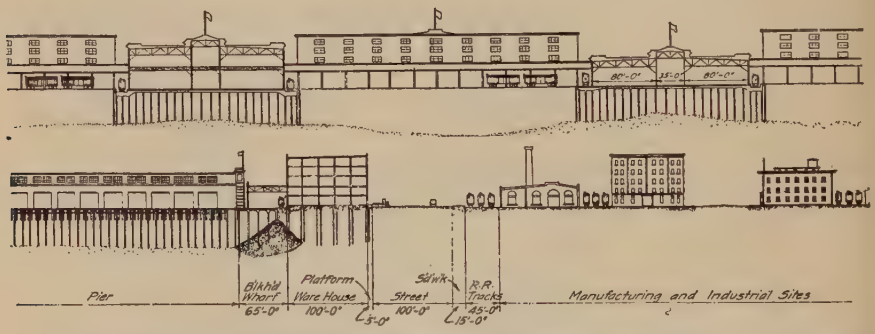


FIG. 162.—Pier and bulkhead warehouse layout planned for Islay Creek Section, San Francisco. Piers are 1,000 feet, possible 1,500 long by 235 feet wide. Slips 350 feet wide with a bulkhead warehouse 350 feet long by 100 feet wide across a bulkhead apron wharf 65 feet wide.

along the waterfront street on the side away from the water. In criticism of this bulkhead warehouse layout, it may be noted that the 65-foot slip wharf has added 65 feet to trucking distances without any apparent compensating advantages. Also, the pier entrances without buildings are wasteful of terminal area where space is limited. The nature of the subsoil may have made the wide apron wharf necessary to insure stable foundations. Also there may not be enough warehousing business in prospect to utilize any more warehouse space.

Quay Wharf and Parallel Warehouses. Type 4. (Fig. 163.)—*At Houston, Texas,* this particular series of typical cross-sections is illustrative of three classes of ship-side commodity storage. The merchandising warehouse is located well inland with a long bridge or gallery for trucking and for conveyors. As the land rises rather rapidly at Houston from the level of the canal, the wharf deck is on a much lower level. The second

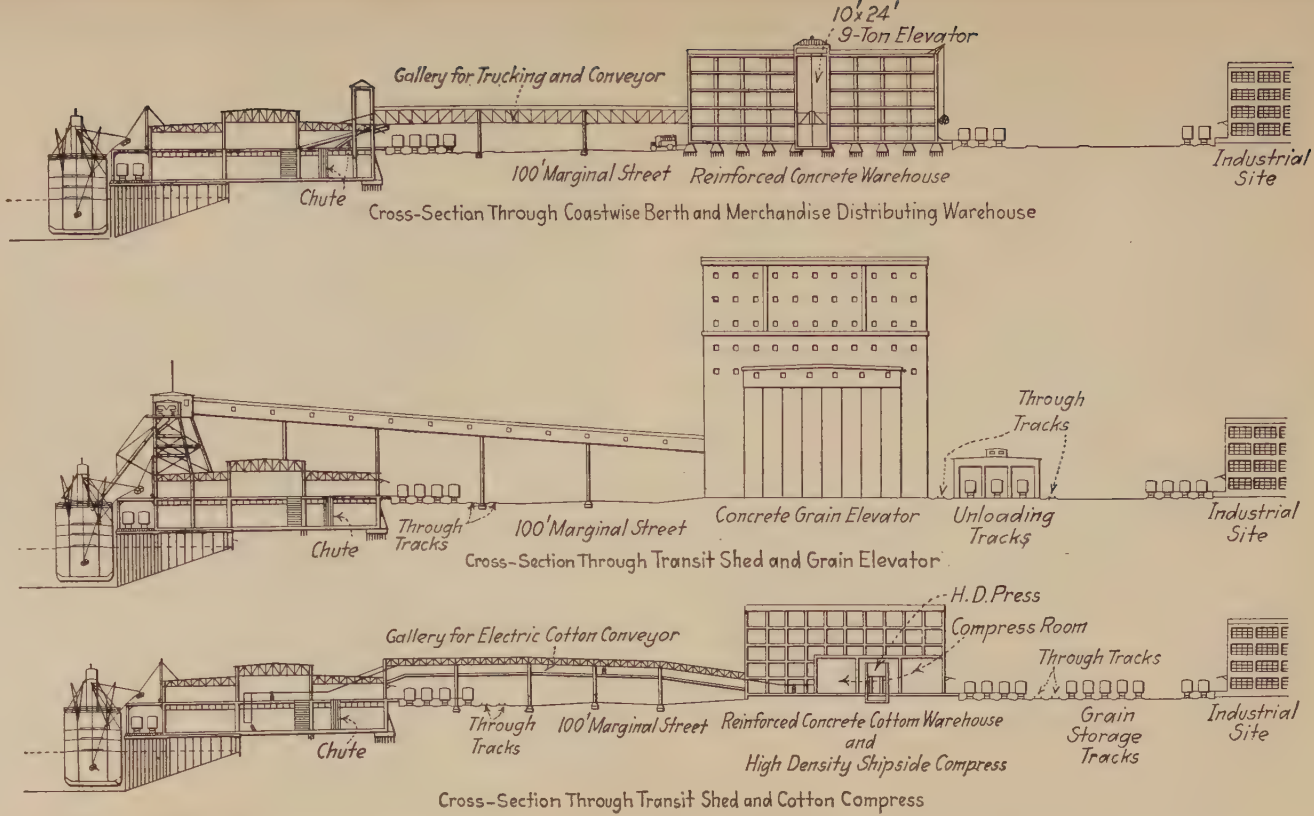


FIG. 163.—Quay wharf and parallel warehouses at Houston, Texas. (1) For coastwise general merchandise distribution. (2) Grain export, (3) cotton export.

deck of the transit shed on the quay wharf is at street level and vertical transfer is necessary to reach the level of the galleries which span the marginal street that serves both rail and truck. In addition to six spotting tracks in the rear of the second floor of the transit shed, there is a 100-foot marginal street, or a distance of almost 200 feet between transit shed and warehouse. The location of the warehouse is quite similar to that at the Brooklyn Army Base.

A grain elevator and a cotton compress occupy corresponding positions at other points along the quay wharves. Grain conveyors connect the grain elevator to grain galleries above the transit shed for loading grain into ships. An electric conveyor of the overhead telpher type to the cotton warehouse maintains direct mechanical connection between the inshore cotton compress and warehouse and the ship.

The Quay Pier with Parallel Center Line Warehouse. Type 5.—The parallel warehouse in the rear of the transit sheds (Figs. 159 and 12) is familiar from the cross-sections of Bremen (Fig. 157) and Gothenburg (Fig. 158). As stated above, this layout gives excellent coordination for transit storage where merchandise moves from transit shed to warehouse directly in the rear, but offers no coordination with lighters, except back over the transit shed and deep-water quay, in case the merchandise from the ship, having been discharged and warehoused, must move to some warehouse at a considerable distance.

The quay pier, with central, parallel warehouses, is in principle an elaboration of the Bremen system. In this case, the warehouse occupies the space in the center line of two quay wharves placed back to back. This system is a vast improvement over the old methods of indiscriminate locations of the warehouse but suffers from the same lack of water connection for pure merchants' warehouse service, thus throwing the entire work of physical quay-warehouse connection upon trap cars or motor trucks moving lengthwise of the quay. A good example of the type of center-line parallel warehouse and quay pier is to be found at Los Angeles (Fig. 159 as originally planned). This quay pier has a total cross-section of 650 feet. From right to left the dimensions are: wharf apron, 20 feet with one track; single-story transit shed 100 feet; loading platform 10 feet 4 inches, to center of first track 7 feet 2 inches. Two additional tracks on 13-foot centers with a space from the center of the last track to the guard rail 16 feet 6 inches, and a spare strip of 18 feet for future spotting tracks. There is a roadway of 68 feet to the warehouse. The warehouse is 150 feet across carrying two tracks on the interior on the ground floor. Then follows 68 feet of roadway and the same features for 174 feet to the water's edge, there being a string piece of only 6 feet 3 inches. In the case of Los Angeles, the layout is for the accommodation of rail traffic primarily. There is little prospect of a large dependence upon lighters being necessary; therefore, ample room for spotting tracks

is more desirable than proximity to a lighter canal. An increase of 100 feet in the width of this quay pier and provision for three tracks in the rear of each transit shed, instead of a possible five on each side, would have given ample room for two rows of somewhat narrower warehouses with a lighter canal between them, as at Hamburg. The paln suffers from lack of easy connection between transit shed and warehouse.

The quay pier with a center-line, parallel warehouse has become almost standard practice in Pacific ports. For instance, at Honolulu Harbor, the Kalihi Annex Basin has a series of slips 200 by 100 feet with a wide quay pier between carrying transit sheds, in this case called segregation sheds, which is not such a bad name for them as they are used for the segregation of marks according to consignees. A center-line warehouse occupies the space between two transit sheds. In like manner, the plans at Tacoma, at Astoria, at Portland, the huge Parr Terminal project for Oakland on San Francisco Bay (Fig. 12), and many other examples show this trend towards a quay pier with parallel warehouses.

Again we have the criticism to make that, although they are a very efficient arrangement for use in transit warehousing, they have the drawback of inflexibility of movement and their great dependence upon trap cars or drays when used by merchants in carrying on their business.

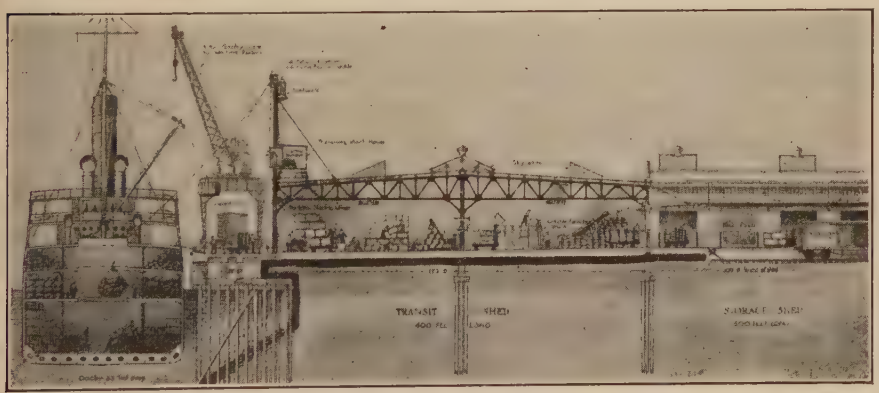


FIG. 164.—Type 6 with marginal quay and adjoining right angle or finger warehouse, Wilmington, Delaware.

The Quay-transit Shed and Adjoining Right-angle Warehouse. Type 6. This type is found at the new terminal at Wilmington, Delaware (Fig. 164), and the Army Supply Bases at Charleston (Figs. 169 and 170) and Newark (Figs. 171 and 172). These three are *extensive* development plans, that is, single-storied structures spread out on low-priced land. In the case of Wilmington, the first section that was built shows an advantage in shorter trucking distances over the situation at Charleston,

inasmuch as the transit shed is 120 feet in width and the warehouses ranged at right angles only 500 feet long. In the case of Charleston, the transit shed is 150 feet wide and the warehouses 1,200 feet long, resulting in the long trucking distances shown in Table VIII. The traveling winch house to operate the burton tackle is an interesting innovation.

THE UNITED STATES ARMY BASES

History 1918–1925.—The most ambitious terminal-warehouse construction on record was carried out by the United States Army during the World War. A series of ocean terminals was erected at a total cost of more than $150,000,000. They were located at Boston, Brooklyn, Newark, Philadelphia, Norfolk, Charleston, and New Orleans. General George Goethals, the builder of the Panama Canal, as Quartermaster General, was the chief officer in charge, and the plans came under the Storage branch of P. S. and T. (Purchase, Storage, and Traffic) Division, Colonel (for the emergency) Wells. The late B. F. Cresson, Jr., was an advisor, and also Francis Lee Stuart and many others. The construction of the bases came under the Constructing Quartermaster, Brig.-Gen. R. C. Marshall, United States Army. The writer, as a very small cog in one of the many wheels, remembers distinctly a conversation with General Goethals on the subject of permanent versus emergency construction of the bases in which General Goethals expressed his feeling that, with American ports backward in modern terminal equipment, these bases for a comparatively small additional cost of permanent construction could become a permanent addition to the nation's port facilities. This policy was followed to the great advantage of American foreign trade and shipping. The fact that a great, world-wide, shipping depression followed the World War which prevented a full peace-time utilization of them, does not detract from the fact that the war-built terminals are a national asset. Also, they are the first attempt in America at truly modern port terminal facilities. That many criticisms of details can be made is obvious. In fact, they were intended as great practical laboratories in which to work out through usage, under operating conditions, better methods of layout, construction, and operation. The anticipation that the various cost of operation elements would be studied by means of a uniform system of records has not been gratified, as the bases have been operated by various interests and without either records or uniformity. There are, however, some factors that may be studied by deduction, such as the trucking distances from ship side to waiting railroad cars as in Table V (p. 212), and in the trucking distances from ship side at the center or far corner of the transit shed to the nearest, the average, and the farthest point of deposit for storage in the warehouse, the results being shown in Table VIII. The study of these relationships

a new field. Similar studies of similar elements in terminal operations is should be made inductively from actual performance as well as deductively, and the tabulated results, both qualitative and quantitative, opened to the studies of terminal and operating engineers.

Since the war, the Army Bases have had a checkered career. Immediately following the Armistice (February, 1919), a committee was appointed "to study and report on the best method of commercial use of the Army Supply Bases." Brig.-Gen. Frank T. Hines, Chief of Transportation, under whose jurisdiction the bases then were, was Chairman; Maj.-Gen. William Murray Black, Chief of Engineers, represented the Army, and Rear Admiral Guy Burrage, the Navy, and the writer represented the Department of Commerce.

The studies of this committee recommended among other things: (1) that the bases should be retained by the Army for national defense; (2) that they should be leased to local port authorities for operation for not less than 10 nor more than 25 years, with recapture by the War Department in case of National Emergency; (3) that ships of the Army and Navy, then the Shipping Board, should have preferential treatment when berthing at these terminals; (4) that the war cost should not be taken as the bases of rental, 5 per cent interest plus 2 per cent amortization, but some fraction thereof to be determined in each case. These are the outstanding conditions as we remember them after 6 years. Part of these conclusions, however, may have been reached in the second, enlarged committee that was appointed the following winter.

No definite action came out of this. Charleston was leased to a quasi-public operating company; Norfolk, Philadelphia, and New Orleans to the local municipal port authorities. The result was unsatisfactory *because financial returns to the War Department by law went into the United States Treasury* and the War Department had to maintain the terminals out of current appropriations for barracks and structures, moneys insufficient to maintain properly the Army posts themselves. Also the group of public officials changed. General Hines went into the steamship business; General Black was retired for age; Admiral Burrage went to sea. Mr. Chamberlain (second committee) retired as Commissioner of Navigation with the old administration, as did the writer as Director of the Bureau of Foreign and Domestic Commerce. The Transportation Corps was merged with the Quartermaster Corps. In fact, the entire personnel was so completely changed that General Connor, General Hines' successor, did not know that the reports of the two committees were in his files until his attention was drawn to it from outside.

To relieve the situation, under the Merchant Marine Act of 1920, Admiral Benson requested the President to transfer the properties to the United States Shipping Board Emergency Fleet Corpora-

tion. This would make possible the application of receipts from operations of the bases to their maintenance. President Harding had approved, but had not signed, the transfer prior to his death. President Coolidge required a little time to orient himself in his new and heavy duties, but finally the transfer was made and new contracts have been drawn for the commercial operation of the bases, largely during 1924. Long-needed repairs have been or are being made. The Atlantic Terminals Companies are operating Boston, Brooklyn, Philadelphia and Norfolk, Newark has been up for sale. The municipal Port Utilities Commission of Charleston and the Board of Commissioners of the Port of New Orleans are operating those two bases. However, what is most needed is more commerce, more demand for these huge terminals. But the seven lean years seem to be about over, and with increased shipping, the terminals will be used to serve the increasing demands of commerce. To Admiral William S. Benson, almost the only official in Washington to hold over and to give any continuity to the interest in these terminals, is due much credit for cutting the Gordian knot and putting the properties in a position to be maintained and used, even if not fully nor to the satisfaction of all concerned.

With all the difficulties concerning maintenance and operation of the bases during these 7 years, it is not strange that the laboratory studies should have fallen by the wayside. In fact there was not a set of layout plans drawn to scale to permit comparisons. Such a set was necessary before even the comparatively simple trucking-distance tables could be made and the true distances visualized. Therefore, we[1] have had prepared the six plans to the same scale from a most heterogeneous collection, suppressing details unessential to this study for the use in this book. These plans with corresponding air views of the bases follow and are the first set in a comparable form.

The problem of trucking distances as the most important factor in operating costs and in the consideration of the installation of mechanical handling equipment received the writer's attention in the preparation of a paper for the American Association of Port Authorities in 1920. More recently the question of trucking distances has been of very active importance in the many considerations of operating the Army Base at Charleston. The study of comparative trucking distances, in the case of the several different types of Army Bases, on the plans drawn to the same scale, has brought out more striking variations in the advantages and disadvantages of the several layouts than even anticipated. The facts shown by Table VIII should have considerable attention and in the future be of great influence when considering the location of warehouses with respect to the waterfront.

[1] Drawing by H. F. Church, Captain, Staff Specialist, Officers Reserve Corps; Assistant Commissioner, Bureau of Port Development, Charleston, S. C.

AREAS OF TRANSITSHEDS AND WAREHOUSES UNITED STATES ARMY SUPPLY BASES

Location		Transit sheds (sq. ft.)	Floors	Warehouses (sq. ft.)	No. warehouses	No. bays
Charleston		265,613	1	1,151,520	6	78
Boston	Main Unit	327,600	2	1,651,104	1	
	Navy Pier	554,400	3			
Brooklyn		1,050,850	2	4,499,640	2	
Norfolk		749,300	1	2,105,600	8	94
New Orleans		560,000	2	1,512,000	3	
Newark		371,200	1	1,670,400	9	12
Philadelphia		.....	3		2	
Hoboken		1,090,698	2	476,511		

Characteristics of the Different Layouts of the Army Bases.—As stated, the various bases were built by General Goethals to different theories of terminal design with a view to: (1) serving the emergency; and (2) affording a basis of comparison during future commercial use.

Boston.—The Army Supply Base at Boston (Figs. 165 and 166) is of the quay type with parallel warehouses, of intensive development and with multiple stories. This discussion does not refer to the multiple-storied Navy pier at the outer end of the terminal discussed under Piers, but to the main portion of 1,638 feet. Aside from minor criticisms, such as the tracks on the wharf apron being located too far inboard of the water's edge to be easily reached with ship's tackle, thus throwing an over-dependence upon gantry and wharf cranes, the Army Supply Base at Boston combines more of those advantages that the writer believes to be desiderata of a waterfront warehouse than any other type.

The bridges crossing the marginal street from the transit shed are less liable to congestion. Figuring on a basis of approximately two bridges per ship, it will be seen that trucking congestion on these bridges is less liable to occur than on the bridges connecting the warehouses at South Brooklyn or New Orleans by a ratio of 8 to 1 in theory or 4 to 1 in practice. South Brooklyn bridges, as can be seen on Figs. 167 and 168, connect a pier that will berth two ships and perhaps four. Assuming four ships to be the capacity of the pier or two being worked in practice, as discussed previously, we will find that all the trucking from the four or two ships must go over one bridge. This will mean twenty or ten hatches, while at Boston the trucking over any one bridge will be from only half a 500-foot ship, or two main hatches. The bridge at South Brooklyn must accommodate the interterminal traffic of ten to twenty main hatches compared with those of Boston two main hatches.

(*Official photograph reproduction authorized by the Chief of Air Service, U. S. A.*)

FIG. 165.—Supply Base Boston. Quay type or parallel system. Note Navy pier type-double pier multiple story sheds. Note Navy graving dock.

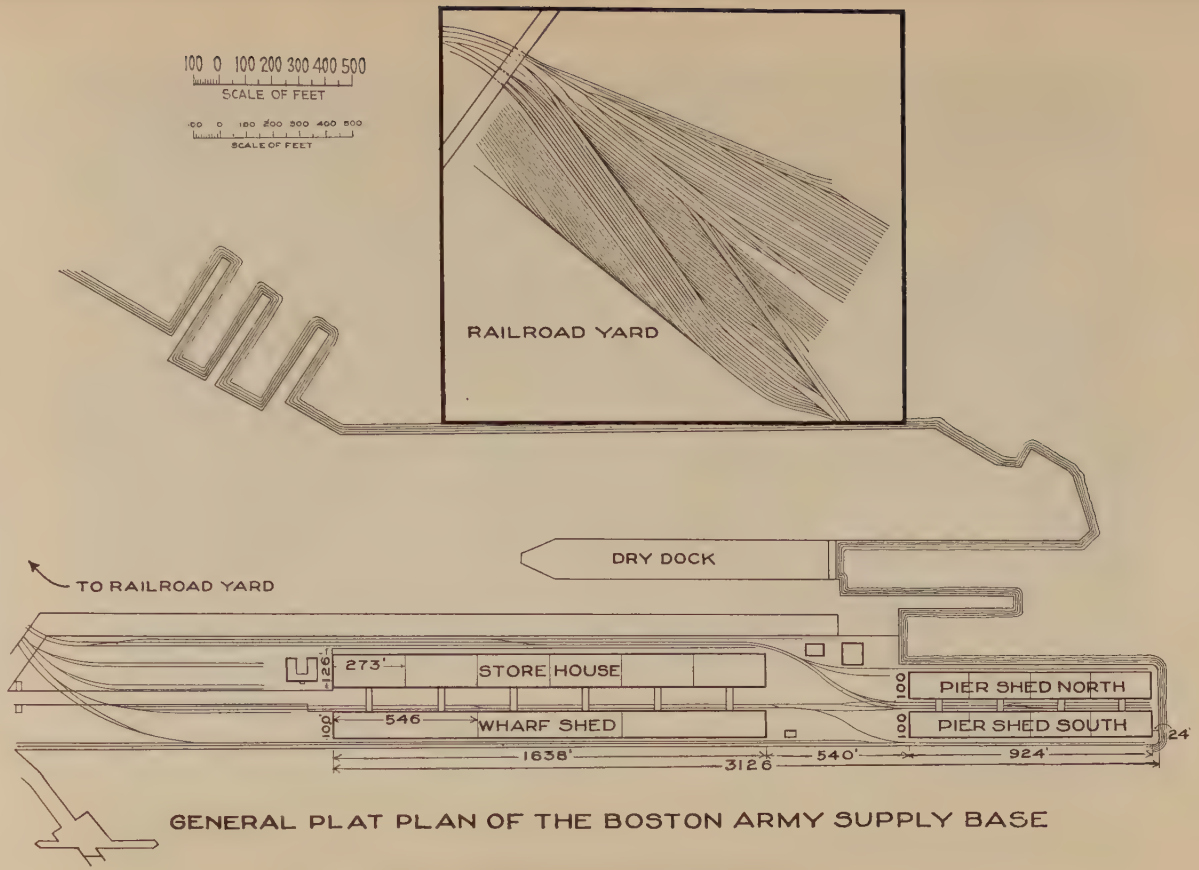
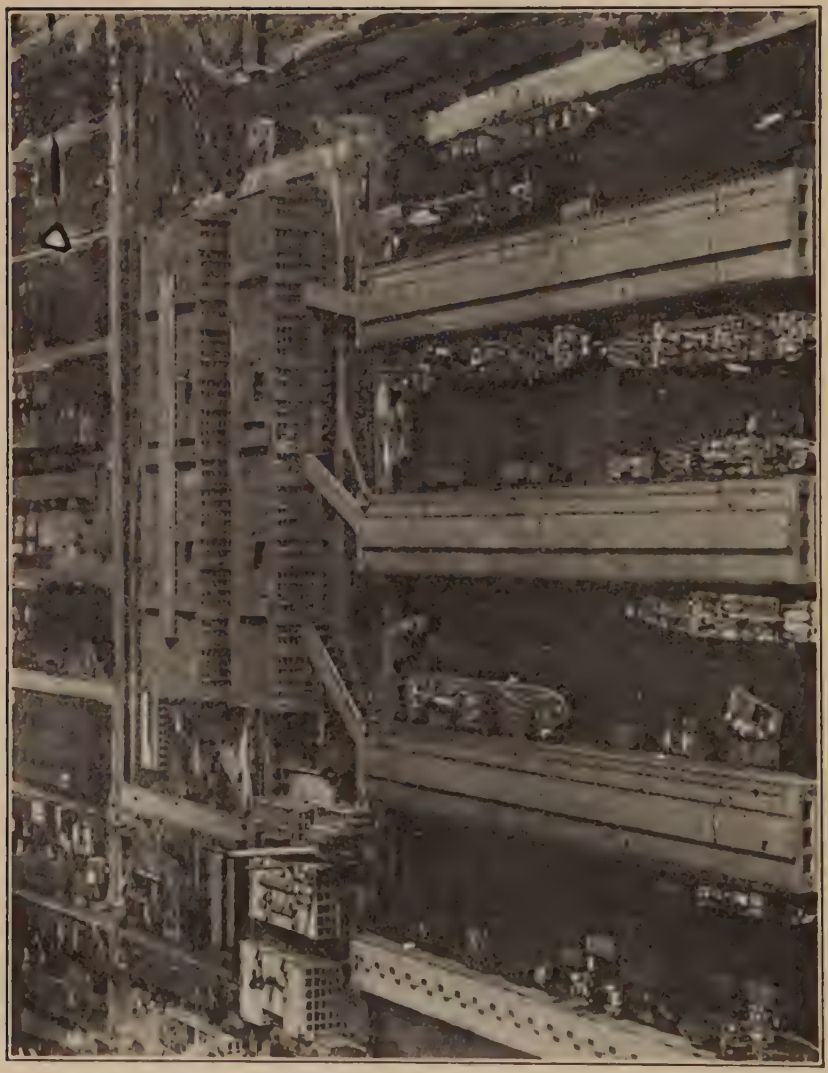
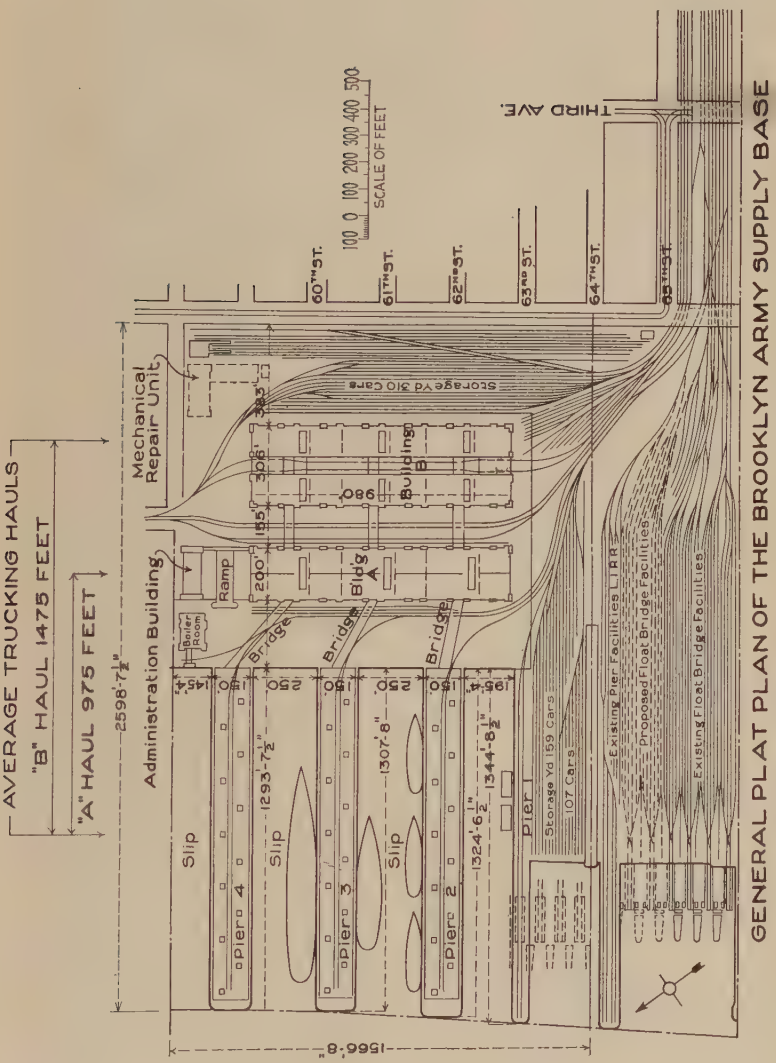


FIG. 166.—Quay type with parallel warehouse.



(*Official photograph Air Service, U. S. A.*)

FIG. 167.—Brooklyn Army Supply Base.

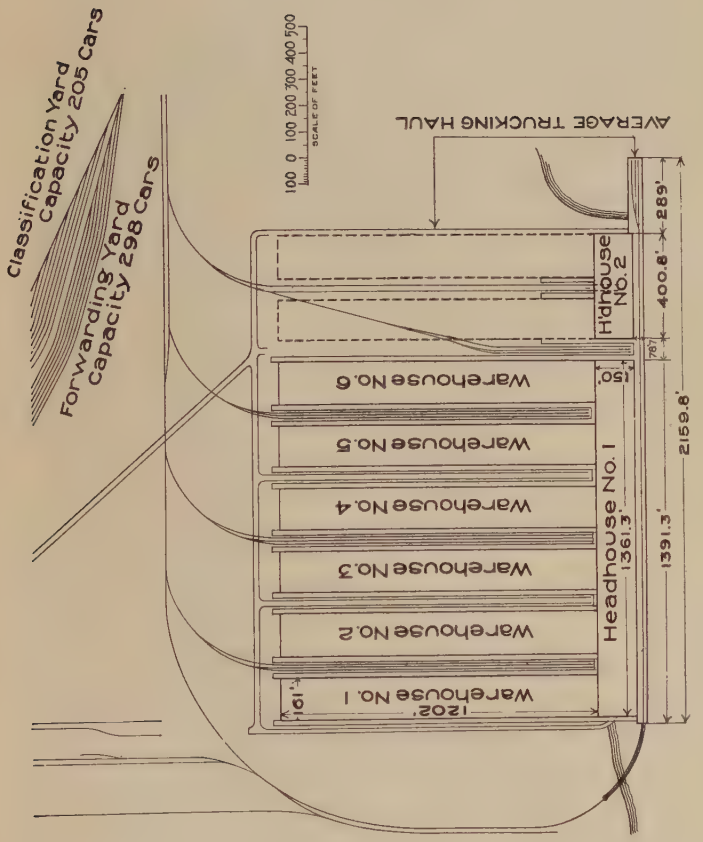


GENERAL PLAT PLAN OF THE BROOKLYN ARMY SUPPLY BASE

FIG. 168.—South Brooklyn. Pier type with inshore warehouses, parallel.

(Photograph by Fairchild Aerial Surveys Co.)

FIG. 169.—Charleston Army Base. Finger type; quay wharf and right angle warehouses.



GENERAL PLAT PLAN OF THE CHARLESTON ARMY SUPPLY BASE

FIG. 170.—Charleston Army Base.

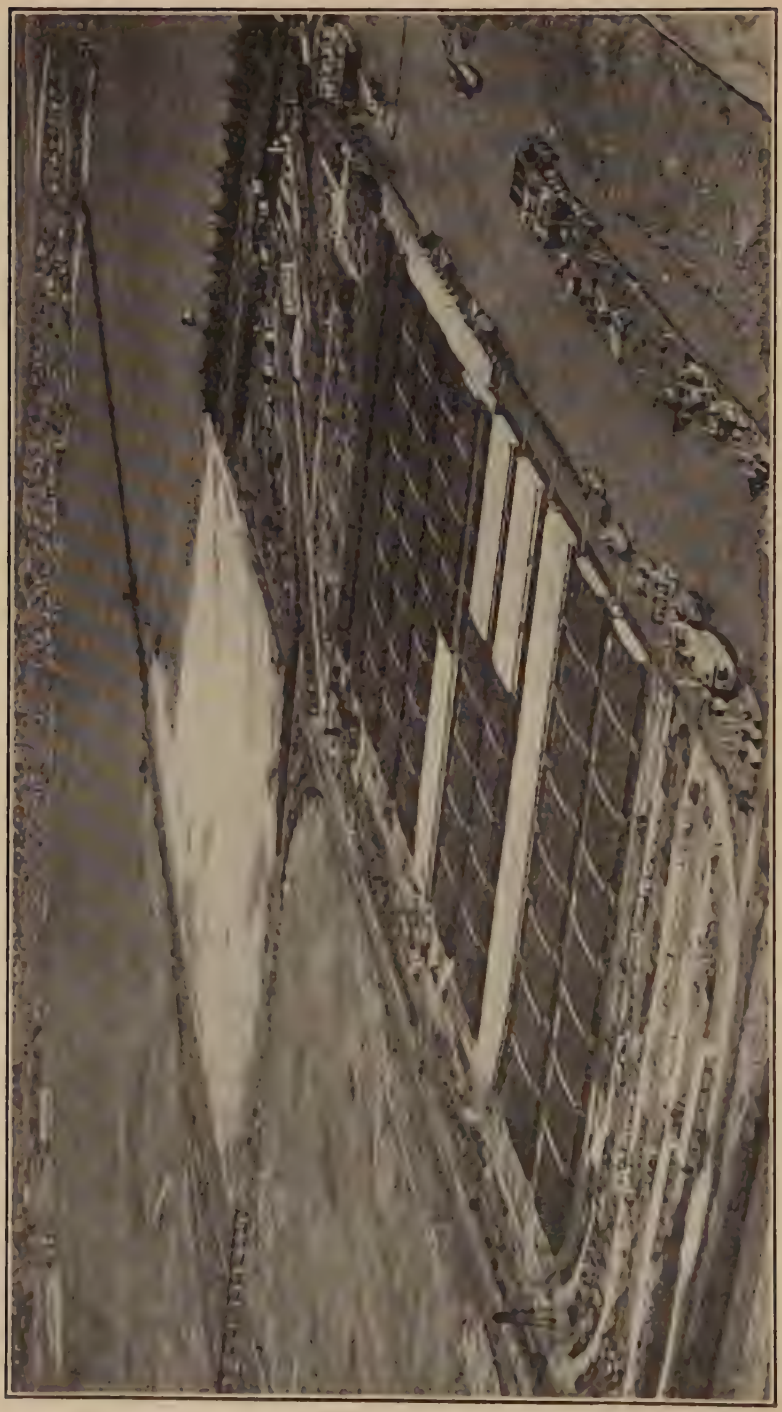
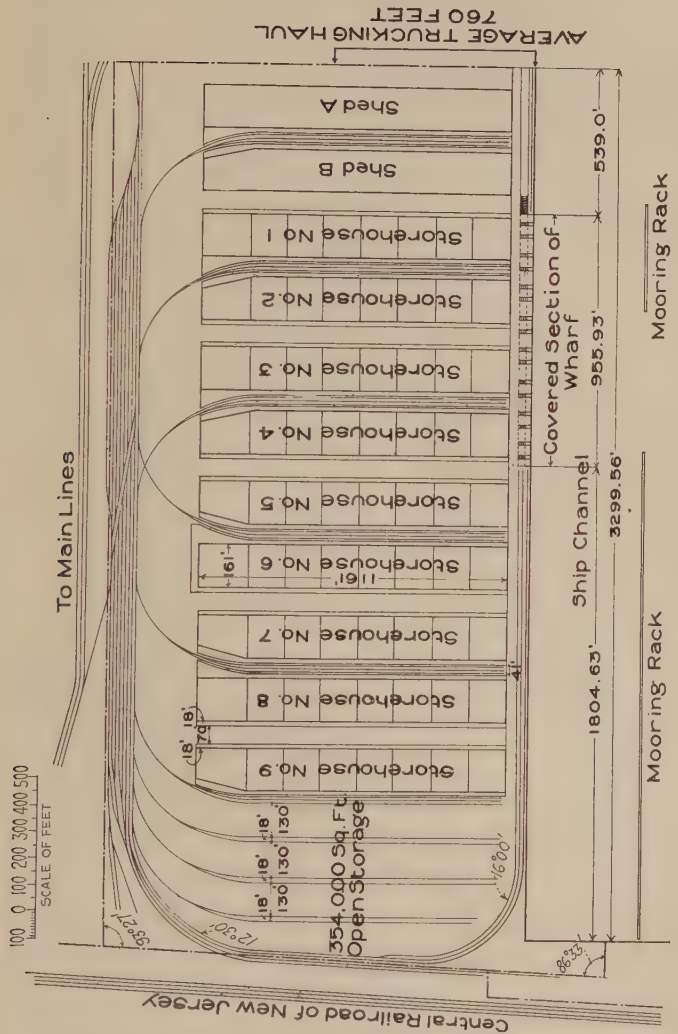
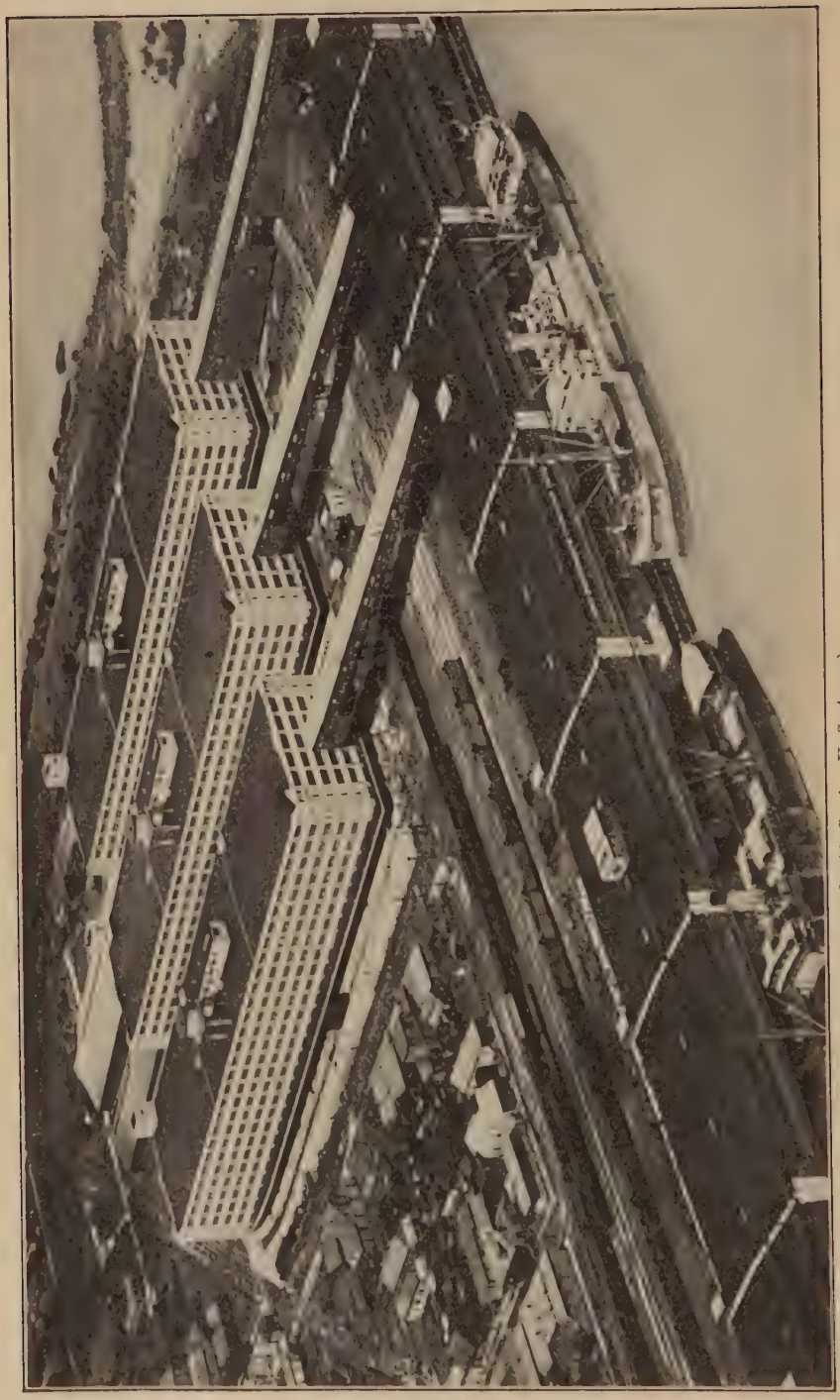


FIG. 171.—Newark Army Supply Base—quay and finger warehouse type; right angle warehouses.



GENERAL PLAT PLAN OF THE PORT NEWARK ARMY SUPPLY BASE

FIG. 172.—Newark Army Supply Base.



(*Official photograph publication authorized by the Chief of the Air Service, U. S. Army.*)

FIG. 173.—The New Orleans Supply Base. Quay type wharf and upland warehouses at right angles.

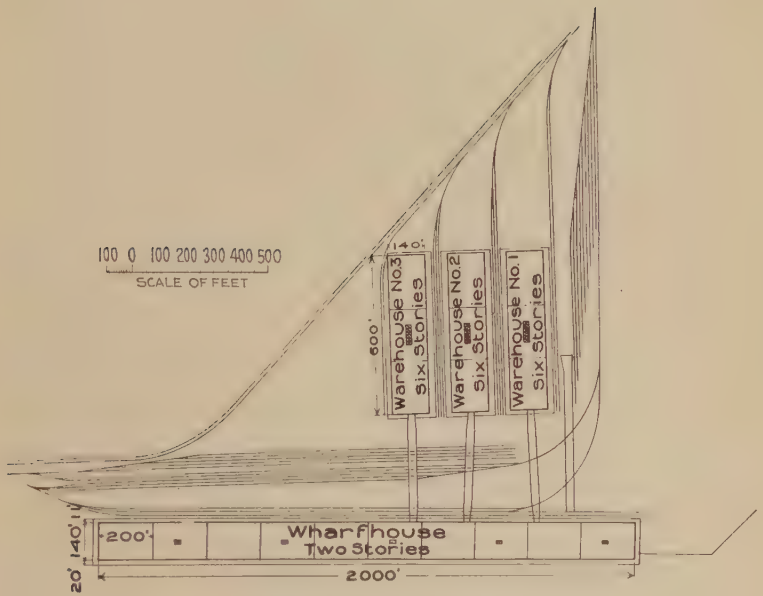


FIG. 174.—Flat of New Orleans Army Base.

Trucking Distance Shortest.—It has already been pointed out that the trucking distance between the center line of the transit shed and the center line of the warehouse is the shortest possible at Boston, of all the Army Bases. It is less only at China Basin, San Francisco, or at the multiple-storied transit sheds, Philadelphia Base, or at the Navy Pier, Boston.

Cubical Content.—The sections of the warehouse approaching a cube in form, have the greatest amount of square and cubical space for their walls and windows and the land occupied, of any type.

Minor Advantage.—Also the marginal way between transit shed and warehouse affords ample motor truck access, while a series of tracks on the land side gives ample access to railroad connections.

The question of lighterage in the case of the Boston Base is taken care of at the deep-water wharf because the trucking distance from the warehouse and transit shed to the water's edge is short, thanks to the compact layout of the terminal. However, if the railroad tracks had been placed through the center of the warehouse on the ground floor and a lighter canal had been constructed at the back of the warehouse, the ideal flexibility of warehouse layout would have been achieved.

Charleston.—The quay wharf with right angle adjoining warehouses (finger type) is typified at the Charleston Base (Figs. 169 and 170). This is also of the single-story type and fire-resistant construction and is thoroughly sprinkled as are all these bases. The fault with the wharf is in the fact that there is only one track on the apron where there should be two tracks and crossovers. Also the first track is too far from ship side. The transit sheds are exceptionally wide making a very long trucking distance from the ship to the first car. The warehouses are of satisfactory arrangement in compactness with fire walls (visible above the roof in the air view) dividing seventy-eight compartments. They are well lighted with skylights and served by alternating rail and team tracks. The far unit back of the transit shed, that will be noted in the distance in the air view, is a spot where two warehouses stood. These were filled to capacity with cotton linters and burned in spite of fire-resistant construction. However, these warehouses were only of light shedding while the wharf shed, being of fire-resistant hollow-tile construction, withstood the intense heat and remained as shown in the photograph. This terminal offers nearly 1,500,000 square feet of sprinkled storage space. With minor exceptions of the track arrangements that are now being corrected, this terminal is the most compact and satisfactory form of the extensive or ground-storage type of warehouse and wharf.

Newark.—Waterside warehouses at right angles to the waterfront of the ground-storage type is illustrated by the Newark Supply Base (Figs. 171 and 172). Except for the transit shed, which is lacking, this base is quite similar to the one at Charleston. However, by omission of

the transit shed and by placing the warehouses and tracks close to the bulkhead, certain advantages are gained in trucking distances for the service of lighters that do not require a transit shed.

New Orleans.—The marginal wharf, with right-angled, multiple-story warehouses type, is shown at the New Orleans Base (Figs. 173 and 174). In this case, the marginal wharf with a 140-foot wide, two-storied transit shed extends along the river. A considerable distance inshore (Fig. 180), due to the instability of the subsoil are located three six-story warehouses at right angles to the waterfront. Because of the peculiar natural conditions to be overcome, the trucking distances between ship side and warehouse are very great. These trucking distances are increased due to the fact that the elevators are in the center of the building. Theoretically, the bank of elevators should be in the middle of the warehouse in order to be nearest to all points, but in practice, transit-shed merchandise moving to and from the warehouse will have to back-track on every other floor except the third floor with which the bridges connect. The electric truck coming from the ship lying in the foreground of the air view and going to the front compartment of the top floor of the first warehouse will travel the length of the wharf to the bridge, across the bridge through the warehouse to the center, where it will be elevated to the top floor and then back half the length of the warehouse. The elevation should take place close to the entrance of the bridge leading to the wharf.

It is further pointed out that no provision is made for direct lighter connection into the warehouse except over the wharf.

Due to the necessity of rapid construction during the war, at a time when the river happened to be very high, the piles could not be cut off as low as otherwise would have been desirable. Consequently, at a later time at low water, fire brands drifted under the wharf and set fire to the piling which burned out completely and destroyed the entire wharf (Fig. 42). The Board of Harbor Commissioners have reconstructed 400 feet of this wharf to date (October, 1925).

Norfolk.—The double pier and right-angled supporting warehouses are typified at the great Norfolk Base (Figs. 175 and 176), in area the largest base constructed during the war. Every element in this great terminal is coordinated, but at the cost of very great trucking distances. The double piers are of such width that their 1,200 feet of length are usable at all points and on both sides. In fact, Colonel Wells and Mr. Cresson considered seriously extending these piers to 1,800 feet, inasmuch as the piers themselves are the quay-pier type, and as the three tracks in the center line between the platforms of the two transit sheds, and also two tracks on the aprons (except on the south side of Pier No. 2 left), are ample to permit the working of any number of ships along the entire length of both sides of the pier. The supporting warehouses, eight in

(*Authorized photograph, Air Service, U. S. A.*)

FIG. 175.—Norfolk Army Base. Type: Piers and right angle finger warehouses; ground storage. Total pier space 796,800 sq. ft. Total warehouse space 2,105,600 sq. ft.; area of the terminal reservation 950 acres. Eight warehouses 1,400 feet or 1,600 feet by 160 feet. 94 compartments. Piers 1,300 feet by 300 feet.

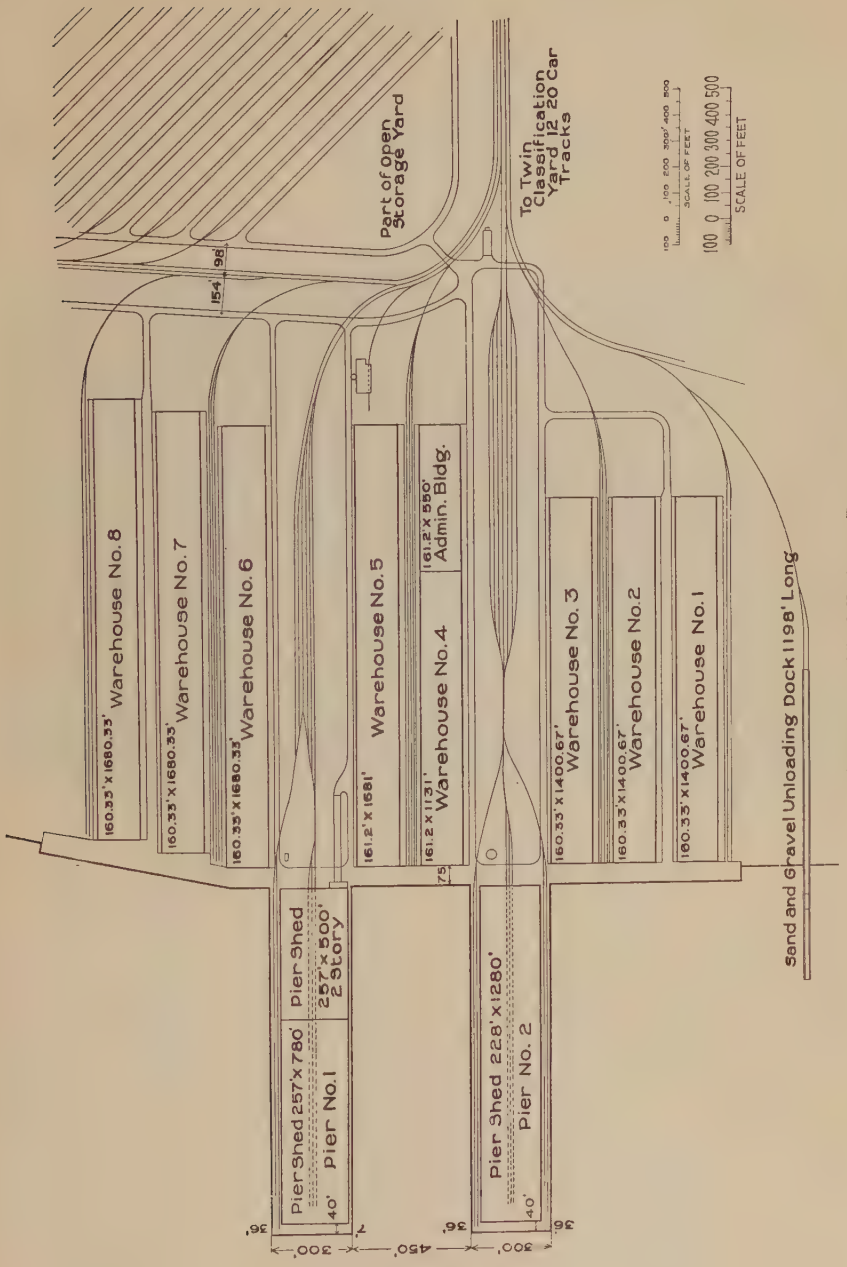

Part of Open Storage Yard
To Twin Classification Yard 12 20 Car Tracks
154
98
160.33' x 1680.33' Warehouse No. 8
160.33' x 1680.33' Warehouse No. 7
160.33' x 1680.33' Warehouse No. 6
161.2' x 1581' Warehouse No. 5
161.2 x 1131' Warehouse No. 4
161.2' x 550' Admin. Bldg.
160.33' x 1400.67' Warehouse No. 3
160.33' x 1400.67' Warehouse No. 2
160.33' x 1400.67' Warehouse No. 1
75'
Pier Shed 257' x 780'
Pier No. 1
40'
Pier Shed 257' x 500' 2 Story
Pier Shed 228' x 1280'
Pier No. 2
40'
36'
300'
450'
300'
Sand and Gravel Unloading Dock 1198' Long
100 0 100 200 300 400 500
SCALE OF FEET

FIG. 176.—Norfolk Army Base.

number, are similar in principle of construction to those at Charleston. However, the area equal to the width of the pier extending inshore separates the groups of three, two, and three warehouses in order to give room for railroad yards serving the pier, while the main break-up and classification yard of the double-ladder type is moved quite a distance and can be seen beyond the two cement roadways extending inland from Pier No. 1 (the one on the right in the air view). To the left, that is, to the north of the running tracks, from the car-storage yards in the rear of the pier and the classification and break-up yard inland, a large amount of material may be seen stored in an area set aside for open

(Official photograph Bureau of Aeronautics, U. S. N.)

FIG. 177.—Navy Supply Base, Hampton Roads, Va.

storage served by spur tracks, also serving cement drayways for team-track delivery. This base was used to a large extent for the handling of railroad supplies.

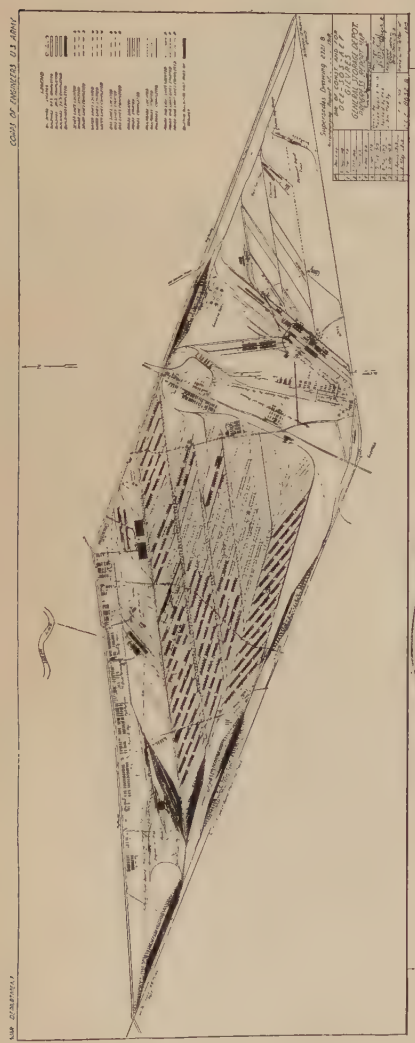
Because of the ample size of the piers permitting great length and full utilization of all parts of the deep-water wharf, it is possible to leave wide slips of 450 feet between the piers, the bulkheads at the bottom of which serve as lighter wharves, thus giving the terminal operator ship, rail, dray, and lighter coordination with transit sheds, warehouses, and open storage.

The only adverse criticism of this excellent terminal is the very great trucking distance from pier to warehouse, the total distance from the outer berth at one of the piers to the last inland compartment of the next adjacent warehouse, tenth compartment, being 4,700 feet, nearly 1 mile.

This terminal, as also in the case of Newark and Charleston, is built on reclaimed swamp land, the sand pumped from the channel dredging used

as fill. As the work was done rapidly for the war emergency, settlement has occurred in several points.

The second floor in Pier No. 2 was used for handling troops and was not designed for the handling of cargo. It could be very easily turned



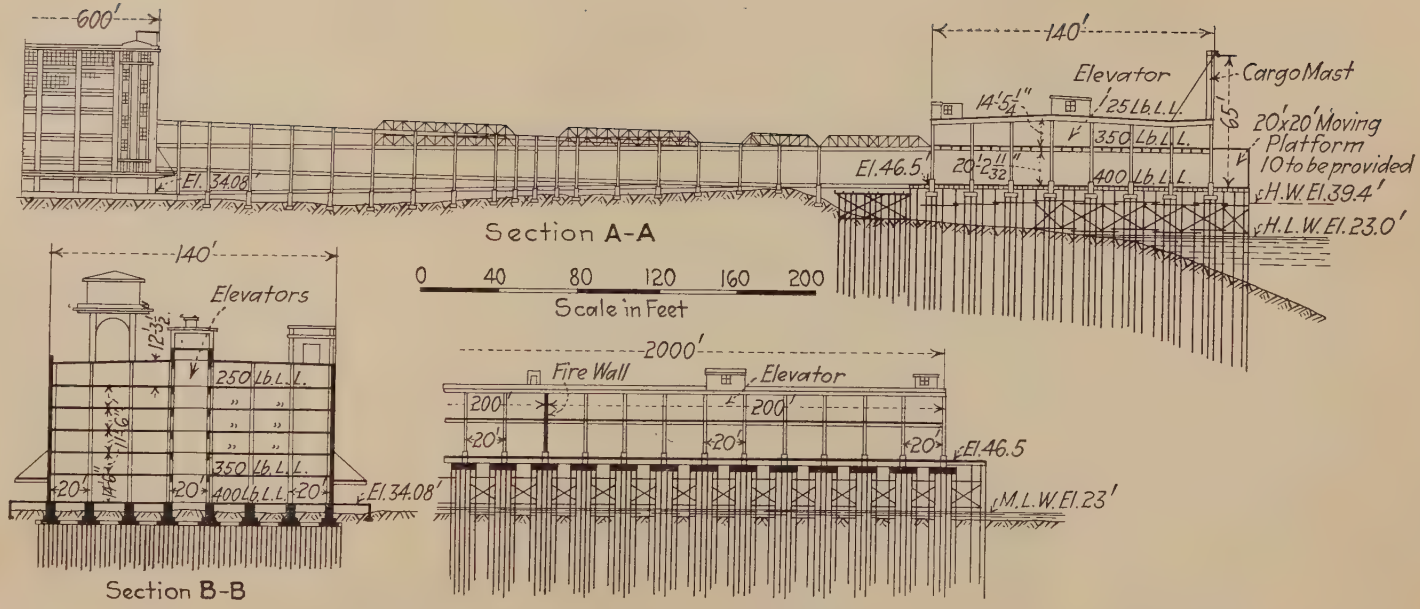
(From "The Military Engineer.")

FIG. 178.—Gièvres, General Storage Depot.

FIG. 179.—Montoir, General Storage Depot.

into a passenger terminal. A similar area is incorporated in the Charleston terminal above Warehouse No. 6 but is not available for passengers, being inland the width of the transit shed.

Brooklyn.—The pier and parallel warehouse type is shown in the Army Supply Base at South Brooklyn (Figs. 167, 168, and 181). In this case three narrow, double-deck piers are connected with huge warehouses



(*Courtesy of the U. S. S. B. Emergency Fleet Corp.*)

FIG. 180.—Army Base, New Orleans. *AA* section (transverse) of wharf showing bridges to warehouses. *BB* section (transverse) of warehouse. *CC* section (longitudinal) of wharf shed.

situated 255 feet inshore from the bulkhead but parallel with it. This is an intensive waterfront development. A great saving in trucking distance could have been accomplished if the ground floor had been left open for rough and heavy storage such as reels of cable, pipe, ordnance, struc-

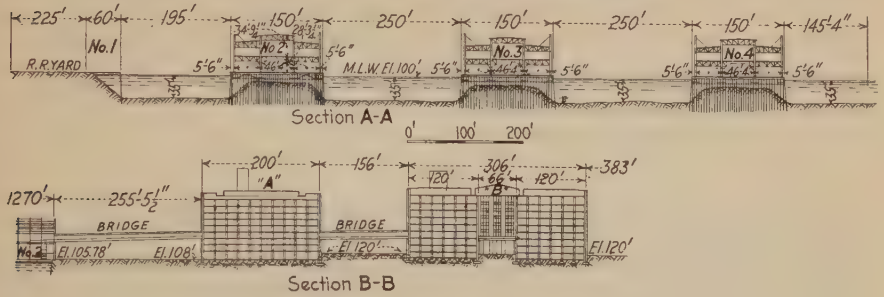


Fig. 181.—The Brooklyn Army Base. Types of existing piers and wharves.

tural steel, etc., and the warehouses had been moved to the bulkhead. Also provision should have been made for lighterage connection, in particular at a port dependent upon lighterage, such as New York. The small space available at the foot of the slips has been used for lighterage

(*Photograph by the author.*)

Fig. 182.—Great covered carloading court in warehouse *B*. Army Base, South Brooklyn with interior elevation to balconies on the various floors by a traveling shop crane.

transfer. This is inadequate for any large lighterage movement and also is still a great distance from the warehouse and requires much long trucking.

The South Brooklyn pier of parallel warehouses is an example of what might be termed "in transit storage" supporting the pier in Warehouse *A*, nearest the water, and merchandising warehousing in Building *B* (Fig. 181).

Architecturally, this terminal is the finest example of warehouse construction that can be found. (Cass Gilbert is the architect.) It is safe to say that the good architectural treatment did not increase the cost of this huge base one dollar.

Rail connection at Warehouse *B* is brought into the light court of the building 66 feet wide between the two sections of the warehouse 120 feet each, making a total width of the warehouse of 306 feet. In this light court, vertical transportation is accomplished by means of a shop crane traveling along cornice rails to both parts of the warehouse, which it was planned would hoist freight directly onto balconies located on the

(Courtesy, George H. Baldwin, President.)

FIG. 183.—A naval stores wharf and storage area at Commodores Point Terminals, Jacksonville. Resin stored in the open, turpentine in barrels under cover or bulk in tanks.

various floors. This is a system that has been in use in various Ford plants. For no reasons given, the shop crane system has been used very seldom, the elevators having the preference (Fig. 182).

Navy Base, Norfolk.—The Navy Supply Base at Hampton Roads, Virginia, gives an example of the pier and right-angle warehouse showing trucking distance increased to a maximum (Fig. 177). Although of splendid engineering construction, the various shops and warehouses from which the Navy is supplied throughout the world are all placed to cause the greatest possible distance for the movement of cargo between ship side and warehouse. The elements discussed in this chapter were not considered in laying out the base.

The piers may seem very narrow, but it must be borne in mind that both inbound and outbound, there is only one consignee, namely, the United States Navy, and large transit sheds for the segregation of cargo according to marks are unnecessary.

Warehousing Naval Stores.—Various special commodities require special warehouse construction. The great cotton warehouses at New Orleans, Galveston, etc., also at Liverpool and Manchester, are examples of special warehouse construction to facilitate the handling of a specific commodity.

Among the special commodities that require separate treatment are naval stores. The naval stores terminal at Jacksonville is shown in Fig. 183. It will be noted that the barrels of resin are stored in the open and on the head. This is to facilitate inspection, as each barrel is broken open and samples taken. The open-storage area is laid off in spaces to facilitate sampling and shipping. On the other hand, the turpentine is handled under cover. It is received in barrels from which it is drawn and pumped into tanks seen in the rear of the long shed. When shipped, it is usually put back into barrels by filling machines at the wharf end, where it is inspected for quality and full barrels. There is no transit shed used as the recoopering is done near ship side and barrels are piled on the open wharf for loading.

Distant Location of Warehouses. *Hamburg.*—It has become almost axiomatic that supporting warehouses should be in close proximity to the waterfront. There are two notable examples where the warehouses or storage areas are a considerable distance from the waterfront, namely: the general storage depots built in France during the war, and the free port warehouse area at Hamburg.

The collection of warehouses at Hamburg are merchandising warehouses for many consignees, reached primarily by water, the goods moving in lighters and shipped out again primarily by water, along the canals and the Elbe by boat, or to ships in the harbor. Some merchandise moves by dray or by rail. In any case, the warehouses are not directly adjacent to the ocean wharf although served directly by lighter canal, drayways, and rail tracks.

War Depots in France.—In the case of the S. O. S.-A. E. F., the depots were a reservoir along a railroad and served by railroad car movements from ship side to depot, further distribution being made by railroad car or motor lorry. These depots were built for in-transit storage, for movement in one direction chiefly, and for one consignee, namely, the battlefield. The Bordeaux *Bassens Terminal*, by means of shuttle trains, moved freight at once, 13 miles to the great depot at St. Sulpice (Figs. 178 and 179).

The Arrangement of the A. E. F. Depots at Gièvres, St. Sulpice, Montoir, Etc.—The covered storage as estimated by the various services was originally 21 square feet per man in the A. E. F., but it was found by experience that for a 90-day reserve, 10 square feet per man was sufficient for supplies actually requiring cover, inclusive of ammunition. This

was later reduced to 5 square feet when a reserve of 45 days was decided upon. These requirements were met as follows:

	Square Feet
Gièvres	3,850,000
St. Sulpice	2,652,000
Montoir	3,456,000
Montierchaume	1,222,000
Is-sur-Tille	1,380,000
Other depots	3,608,000

	Square Feet
Total depot storage	16,168,000
Dock storage	3,213,000
Miscellaneous storage	3,858,000
Grand total	23,239,000

These depots were in direct connection with the various ports of Bordeaux, St. Nazaire, La Pallice, Montoir. The illustrations will show a herring-bone type of general layout of the single-story warehouses served by ladder and spur tracks with adjoining receiving, departure, and classification yards, refrigerating plants, gasoline and oil reservoirs, and ordnance storage at isolated points. The standard type of warehouse was 50 by 490 feet and 12 feet high at the eaves. It required 4,400 square feet of corrugated iron and could be quickly erected. At Gièvres, on one occasion, a warehouse 50 by 294 feet was erected in 8½ hours by 60 men. In this rapid-construction work of short duration, no floors were provided except in buildings where supplies were subject to injury by moisture, such as sugar, salt, and flour. In this system of warehouse depots, inland supplies were stored in transit from all ports to all parts of the front. At the storage project at Gièvres, supplies were received from all ports and held in storage until needed in the advance depots or elsewhere. This project as originally designed contemplated a total trackage of 280 miles, and at the time of the Armistice, there were laid and in operation 143 miles of track, which comprised the 36 miles in the receiving and departure yard, 9 miles in the classification yards, 7 miles in engine terminal, 13 miles in engineer depot for open storage, and the balance, 69 miles, to serve the 165 warehouses, refrigerating plant, and other lesser facilities; Gièvres was the largest of the storage facilities. It covered an area 6 miles in length and 2 miles in depth. There were 30,000 men stationed in camps within the project, 20,000 for construction and 10,000 for operation purposes. Construction work was started at Gièvres by the Fifteenth Engineers (Railway) in September, 1917, and the depot started functioning in November of the same year. The maximum number of men employed on construction was 5,877. Altogether, the Divisions of Construction and Forestry, C. E.-S. O. S.-A. E. F.,

under the directorship of Brig.-Gen. Edgar Jadwin, employed at one time 167,000 men or more than three times the number employed on the Panama Canal at any one period.[1]

"The work of the Division of Construction and Forestry is ably described by Colonel Woodruff, both as regards the difficulties encountered, the results accomplished, and the method by which these results were obtained. I cannot let the opportunity pass without a word as to whom the credit belongs for these splendid results.

"Looking at it in retrospect, my predominant thought is that everybody connected with the work at any time showed a most commendable, patriotic, and intelligent devotion to duty. This applies both to officers and men from the regular army and to those in the army only for the war, and applies also whether the organization be regarded chronologically or from top to bottom.

"With the changing force which at times was as great as 160,000, it is manifestly impossible to cite all the names, much less to specify fully the specific items for which each man should be commended. I cannot, however, let the opportunity pass without including at least the names of the heads of the central office organization and of the construction work in the field, namely,

CENTRAL OFFICE ORGANIZATION DURING MY INCUMBENCY

Col. J. A. Woodruff	Deputy Director.
Col. E. A. Gibbs	General Construction.
Col. J. H. Graham	Railroads and Docks.
Col. E. H. Marks (later Lt. Col. W. B. Greeley)	Forestry.
Maj. Geo. Sykes (later Maj. H. W. Gregory)	Administration.

The construction work in the field was carried on through the following section Engineer officers:

Base Section No. 1—	
Headquarters, St. Nazaire	Col. J. S. Sewell.
	Lt. Col. W. G. Atwood.
	Lt. Col. F. B. Maltby.
Base Section No. 2—	
Headquarters, Bordeaux	Col. J. B. Cavanaugh.
	Col. Hugh L. Cooper.
	Col. Ernest Graves.
	Col. J. R. Holman.
Base Section No. 3—	
Headquarters, London	Col. R. G. Powell.
Base Section No. 4—	
Headqaarters, Le Havre	Col. W. A. Johnson.
	Maj. Geo. S. Brinkley.
Base Section No. 5—	
Headquarters, Brest	Lt. Col. E. V. R. Payne.
	Col. Mark Brooke.
Base Section No. 6—	
Headquarters, Marseilles	Col. R. C. Moore.
	Maj. A. B. Cutter.
Base Section No. 7—	
Headquarters, La Rochelle	Col. J. R. Holman.
	Lt. Col. J. W. Williams.
	Maj. C. C. Cragin.
Intermediate Section, East—	
Headquarters, Nevers	Col. E. N. Johnston.
	Col. Harry Burgess.
	Col. Geo. H. Webb.
	Lt. Col. J. L. Buchanan.

[1] The work of storage in the A. E. F. is a bright chapter in American engineering history and a great credit to American genius in organization. I cannot pass over this point without incorporating, at least in a footnote, the following remarks from *The Military Engineer*, of General Jadwin the head director and moving spirit of the greatest storage in transit enterprise in history.

Intermediate Section, West—	
Headquarters, Gièvres	Col. Ernest Graves.
	Col. S. B. Williamson.
	Lt. Col. E. L. Daley.
Advance Section—	
Headquarters, Neufchateau	Brig. Gen. J. F. McIndoe.
	Col. T. H. Jackson.
	Col. Ernest Graves.

"The forestry work in the field was carried on through district commanders, each of whom also commanded a battalion of Twentieth Engineers (Forestry), with attached service companies which operated from two to eight sawmills.

"Most of the mills were in the advance section and base section No. 2.

"The districts in the advance section were combined under Lt. Col. C. B. Chapman (later Maj. F. F. Spencer), section forestry officer, and those in base section No. 2 under Lt. Col. Raymond E. Benedict, section forestry officer. These officers acted directly under the central office for production and shipments outside their own section, but filled local requisitions on the orders of the section engineer in whose section they were located."

In closing this chapter on the type and location of the warehouse, it is hoped that some contribution to this important problem has been made, although admitting that the subject has been outlined for future study. One thing, however, is certain, the warehouse both for transit storage and merchandising has come to be generally acknowledged as an integral part of any merchandise terminal without which the terminal is incomplete—not modern.

PART III

PORT TERMINAL FACILITIES OTHER THAN GENERAL CARGO. (PASSENGERS, BULK, INDUSTRIES)

CHAPTER XIII

OCEAN PASSENGER TERMINALS

Ocean passenger terminals have received little consideration at the hands of writers on ocean terminal problems. It is a very fruitful field for investigation and thought, as this class of cargo is now receiving the consideration it deserves.

Passenger traffic may be divided into transocean, coastwise, and excursion. The center of interest in this chapter is in transocean traffic, as the same principles, except for customs inspection and heavy luggage, apply to coastwise and excursion passengers.

Ocean travel falls under two main groups—cabin passengers and steerage passengers. Cabin passengers are first and second class; steerage passengers, third and fourth class. There is now a strong tendency to slide third class up into third cabin. This is especially true of the educational tours, or tourist class of travel which is being actively developed to take up the slack caused by immigration restrictions. Little attention has been given to the dispatch or comfort in the handling of any of these classes in the layout of our American port terminals. In most cases, passengers are dumped onto a cluttered pier, cold and draughty in the winter, blistering hot in summer, and more resembling a livery stable or a warehouse than a place for people.

Some of the more modern piers are clean and very well equipped to handle passengers in the amount of space that is available. An example is Pier No. 86, New York, where the *Leviathan* has been docked; also the Chelsea piers and several of the piers of the United States Lines (former Hamburg-American and North German Lloyd properties in Hoboken), and many others using the second floor exclusively for passengers. But these are exceptions rather than the rule. To the ordinary second deck of a cargo pier is added cleanliness and a few conveniences. This type of makeshift passenger accommodation in ocean travel is about to become obsolete.

Cabin passenger travel requires accommodations similar to those of any well-organized railroad passenger station. It must afford dispatch, comfort, and attractiveness to the traveling public. To the principles involved in the construction of railroad passenger depots, the ocean passenger station must also furnish accommodation for customs inspection and other customs formalities. The landings and gangplanks should accommodate themselves to the varying level of the water, and to the

various heights of the decks of the different ships. And they must offer rapid and uncongested connection between the ship and railroad trains, taxicabs, and street cars. The problem is complicated due to the fact that larger numbers of persons are embarked or disembarked at a time than from a pullman train, and through a very few openings or gates. Also the companionways of ships are narrow and cramped, becoming stiflingly hot in warm climates and making torture of any delay in landing.

Cabin passenger traffic of the future will involve the construction of special union passenger wharves with the passenger stations on solid ground and special landing platforms that will rise and fall with the tide. To facilitate berthing the ship, the landing will be parallel with the current. Such terminals will obviate many delays to ship and passenger now inherent in our right-angle pier system.

The loss of time in berthing the ship by warping into a slip against a current can be obviated by passenger ship berths parallel with the current. This delay sometimes amounts to an hour or more before friends and relatives, separated by months of foreign travel, are united on the pier. The parallel berth will admit of quick berthing for the discharge of passengers before the ship proceeds to its cargo, and bunkering berth. Where a considerable variation in water level is the rule, the floating landing stage, such as that of the Prince's Landing Stage at Liverpool, the St. Pauli Landungs Brücke at Hamburg, the Tilbury Stage at Tilbury Docks, etc., will be a helpful solution. The floating passenger wharf will give a fixed or known relationship between the level of the deck of the landing stage and the level of the side ports of the vessels, that can be predetermined from a knowledge of the vessel. Easy grades of the gangplank can then be provided and the gangplanks held in readiness to connect the moment the ship is made fast. Modern ocean passenger terminals are equipped with electrically driven gantry gangplanks capable of speedy adjustment.

Dispatch may be further increased through the better organization of the various inspections so irksome in ocean passenger service, in advance of discharge or sailing because the special landing stage is adjusted in every detail in advance of landing or embarking. And finally, there should be a proper provision for friends and relatives meeting the boat.

Dispatch through Better Organization of Inspections.—Dispatch of passengers at sailing time should involve no more confusion than is experienced in an ordinary passenger-train shed at the Pennsylvania or Grand Central Station in New York. The ship drops down from its dock and in a few minutes makes fast to the stage. A battery of gangplanks is adjusted to the various openings of the vessel. Passengers have been assigned in advance to one of these gangplanks according to

the location of the cabin in the ship. This makes it possible to handle several streams of passengers simultaneously and to check over their baggage, vise their passports, examine their tickets, and have all in readiness, so that the ship may pull alongside the landing stage, receive the passengers who have already cleared through the formalities, and be on her way within an hour or two.

One of the worst cases on record of delay and annoyance to passengers was formerly at Key West en route to Cuba, due to the many inspections: (1) the International Revenue Officer of the Treasury Department to see if income tax had been paid; (2) the passport inspection of the Department of State; (3) ticket inspection by the carrier; (4) sometimes, medical inspection (cursory) by the Bureau of Public Health. Inbound there is the customs inspection. To make each person stand in line three or four times, once for each inspection, is absurd. The various officials by a little coordination can be arranged in such a manner that one queue can pass from one to the other. The dispatch of all four inspections would be at the rate of the one slowest officer. If the volume of traffic exceeded the ability to handle it in 1 hour by the slowest inspection, there should then be as many lines and as many sets of officers as necessary to handle the total number of inspections within 1 hour. Old Russia, under the Czar, was courtesy itself compared with the annoyances, delays, and, frequently, discourtesies of petty officials, encountered by the traveler entering or leaving the United States.

The sailing day, although perhaps more exciting, does not always suffer the congestion that the landing day assumes. This is because a large number of passengers arrive well ahead of the sailing hour, but all are discharged at once, full of impatience to be gone. Moreover, sailing-day psychology is quite different from that of landing day. Sailing day has more excitement but more of a joyous holiday mood. Landing day has more impatience at delays.

Cab and Taxi Congestion at the Pierhead.—At various American ports, and at some European ports, where the pier system is in vogue, disembarking passengers must find their way out of the pier shed to their hotels or railroad stations at one narrow point. For instance, the *Leviathan*, landing several thousand passengers at Pier No. 86, cannot possibly dispatch more than two taxicabs at a time at the entrance to the pier; yet a parallel landing stage with adequate passenger accommodations in the head house for motor cars and taxicabs can simultaneously dispatch passengers from six, eight, or ten different carriage entrances.

Fixed-level Passenger Landings.—Several examples of the fixed-level or permanent-structure type of passenger accommodations may be enumerated before the discussion of the floating type.

At Havre.—One of the most notable examples is that of the French Line—the Compagnie Générale Transatlantique—at Havre (Figs. 184,

185, 186, 187, and 188). This passenger wharf being along a dock at a constant water level obviates the necessity of floating equipment to accommodate varying water levels. But a delay is encountered waiting

FIG. 184.—Upper deck of the Cie. Transatlantique ocean passenger station at Havre, France. The passenger trains are on the main deck.

for high tide to enter the dock. The passenger terminal consists of a two-deck, quay-transit shed. The quay level is a train shed from which are dispatched the express trains to Paris. Trunks and uncrated auto-

FIG. 185.—Benches for customs examination at the ocean passenger station of the Cie. Transatlantique, Havre, France.

mobiles are landed onto the quay level. The main passenger accommodations are on the second deck. This consists of a wide promenade with a wide overhanging roof or shelter for friends and relatives greeting or speeding passengers, and also serving as a landing from the gangplank.

A glass enclosure with frequent doors admitting to the main portion of the second floor of the transit shed affords shelter in inclement weather. The main part of the second or ship deck is equipped with a restaurant,

FIG. 186.—Telegraph office of the ocean passenger station of the Cie. Transatlantique, Havre, France.

telegraph and cable offices, rest and writing rooms, and a large floor area with low benches for easy examination of trunks and hand baggage by

FIG. 187.—Third-class waiting room at the ocean passenger station of the Cie. Transatlantique, Havre, France.

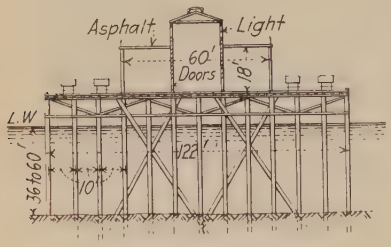
the customs officials. In another portion of the transit shed are segregated third-class and steerage passengers with ample facilities for medical and other examinations, according to the immigration laws. The entire

layout is not a copy of a railroad passenger station, but is a careful design for an ocean steamship passenger station that will do the work for which it was built, the transfer of passengers between ship and railroad to the best possible advantage.

(*Courtesy of the French Line.*)

Fig. 188.—At Havre, special passenger train accommodations are had at steamer's side. Here ocean passengers may transfer under covered piers without inconvenience or delay.

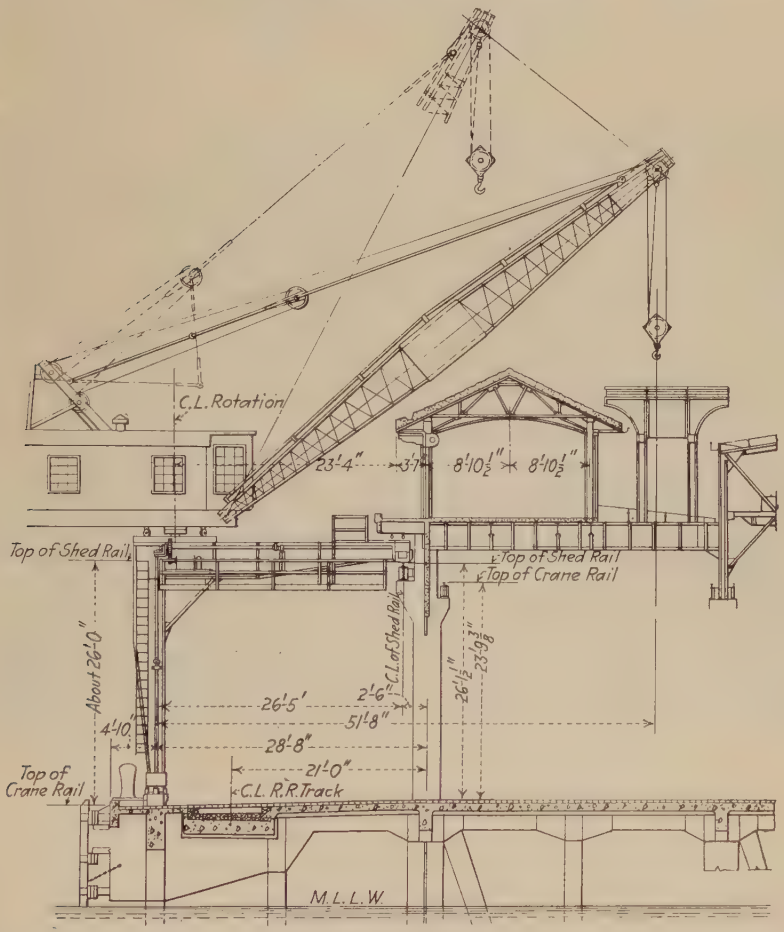
At Hobart, Tasmania.—The passenger pier at Hobart, Tasmania (Fig. 189), receives less intensive use than the passenger station of the Compagnie Générale Transatlantique at Havre, and provides only the promenade feature noted at Havre. The single-story transit shed on the pier is built with three bays, the central bay a high clearstory. This might be termed "the nave." The roofs over the outside bays or "aisles" to the extent of almost one-third of the building are constructed as a boardwalk and passenger landing. This removes the passengers out of the confusion of goods traffic on the main deck. Aside from its use for steamship passengers such a boardwalk is of great political value in modern port development. The people vote the bond issues and purchase them to make possible public port facilities. Ships have a fascination for all classes and all ages. If the public can stroll along a quay-side promenade and watch not only arrivals and sailings of passenger ships, but the loading and discharging



(*Dock and Harbour Authority, London.*)

Fig. 189.—Port of Hobart, Tasmania. Section through No. 2 shed, Ocean Pier. Observe 20-foot wide passenger walk on the second floor (18-feet clearance). This pier is a *passenger* and cargo pier.

of "all the little cargo boats," they will not only be intrigued and educated in ocean shipping, but will feel a sense of pride of ownership in the port facilities to which they have contributed their bit in taxes or the purchase of a bond or so. Such arrangements not only make for good passenger accommodations, but also are good port propaganda.



(Courtesy, E. Clinton Earle, Vice President, Manila Harbor Board.)

FIG. 190.—Cross-section of passenger passageway and landing balcony. Pier 7, Manila, P. I. Cranes by Wellman-Seaver-Morgan, U. S. A.

Manila, Philippine Islands, Pier No. 7 is a splendid example of these two ideas in passenger accommodations on ocean piers (Figs. 190, 191, and 192). The pier itself is constructed on concrete piles and large enough to handle simultaneously the Canadian Pacific *Empress* and the United States Shipping Board *President* ships. The pier was designed by E. Clinton Earle, Port Works Engineer and Vice-chairman, Manila Harbor Board. He writes the author:

Minor accidents to passengers on our other piers and the desirability of eliminating confusion on the pier cargo deck, due to the passage of tourists through the sheds, made it necessary to work up details for the separation of passenger traffic. My search for precedents was not highly rewarded. However, the facilities I finally incorporated in the design have *proved up* and we have no congestion either in the freight department or in the passenger passageway, frequently handling from 350 to 1,200 passengers from ships such as the steamships *Franconia, Laconia, Empress of France, Belgenland, California, Resolute,* and other vessels of similar type on round-the-world cruises. By

(Courtesy of E. Clinton Earle, Port Works Engineer, Manila, P. I.)

FIG. 191.—Balcony 3½ feet wide along passenger passage with gantry gangplank connection with the ship. Pier 7, Manila.

bringing the passengers into the central entrance in the pierhead (truck entrances being located on both sides of the passenger entrance in the pierhead) and lifting them to the elevation of the passenger passageway by elevators, passing them through covered bridges (see photographs) into the regular passenger passageway built along the outer face of the pier shed proper, we find that we are able to handle our passenger traffic without congestion and without interference with working cargo. And what is of equal importance, the passengers are at no time in the slightest danger of being struck by hooks or slings and are in clean and pleasing surroundings. Ships are thus able to work their gear until a few minutes before the gangplank is removed.

The wharf apron is 28 feet wide center to center of crane rail and shed-steel structural verticals or 32 feet 6 inches from outside edge of pier.

The gantry gangplank travels on the gantry crane rails. The top of the shed rail is 26½ feet above the cargo deck of the pier. The covered and enclosed passenger passage is 17 feet 8 inches wide with a balcony 3 feet 7 inches extending over the shed-crane rail. This balcony on the underside carries the crane-power connections. The slant-pipe railing of the balcony is removable in sections at any point to receive the gangplank. There are five crossover passages connecting the passenger passages on both sides of the pier. The central entrance of the pier with its height, spaciousness, and elevators to the passenger gallery has great similarity with a fine modern railroad passenger terminal.

FIG. 192.—Interior view of 17-foot wide passenger corridors, Pier 7, Manila.

Coastwise wharves, such as those of the Clyde Line and the Savannah Line in New York, Charleston, Savannah, Jacksonville, etc., have a somewhat similar platform arrangement to remove passengers from the cargo deck. Elevated passenger-landing platforms are placed at intervals along a single-story wharf with a suspended gallery walk from these landings to the two decked bulkhead house of the terminals where are situated the ticket offices, baggage master, and other accessories to passenger travel. It must be borne in mind, however, that coastwise travel is essentially different in certain respects from ocean travel; the first being the absence of customs formalities; the second, the comparatively small amount of baggage carried by the passengers due to the fact that they are on short trips rather than voyages of several months' duration, as is usually the case in ocean travel. These passenger passageways have been very useful.

Southampton.- This port handles great numbers of passengers. It has its passenger accommodations in combination with the usual quay-side transit shed. The method varies little from that of the larger steamship lines at New York that use the second deck of the piers for passengers. These are undoubtedly superior although Southampton enjoys the economy of direct rail service at ship side. Some other details are better at Southampton. The nature of the traffic at this port is important in considering the problem. This is a railway-owned port and the major part of the business is passenger traffic by special train from ship to London or London to ship.[1]

Floating Landing Places.—One of the principal losses of time in landing passengers is due to the difficulty of warping a great steamship into a pier slip at right angles with the running current, as at New York, or in waiting for high tide to enter the docks, as at Havre. The modern traveler has become so impatient of delays that steamship lines are catering in every possible manner to the desire for quick serivce and dispatch. This question of delay in warping in the ship is one of important consideration in handling passengers.

The remedy at many ports has been found in the floating landing stage parallel with the current of the river or bay at which a ship can berth with a minimum loss of time to load or discharge passengers, proceeding immediately afterward, as the case may be, to sea or to her freight berth for fuelling, provisioning, overhauling, discharging, and receiving cargoes. The objection at New York to berthing the ship twice is based on the idea that the passenger accommodations would be no different from the present right-angle pier and that each berthing would mean the loss of time of several hours. These same ships, at the other side of the Atlantic, land and discharge passengers at passenger landings and unless very unusual wind conditions are prevailing, are able to make fast in 10 or 15 minutes, discharge the passengers and their luggage within an hour or two, and proceed to the freight berth with a loss of probably 1½ to 3 hours altogether.

The writer well remembers, some years ago at Cuxhaven, watching one after the other, the *President Grant* and the *America*, arrive, discharge passengers and baggage, and proceed up the river to their berths at the Hamburg Free Port all within the time between 3 and 6 p. m. There was berthage ample in length to have accommodated several times as many ships, only one berth being occupied that afternoon, the *President Grant* having finished and moved on before the *America* arrived at berth. It is perfectly feasible for a port to have a union passenger station of the "dress landing" type, to use a Navy term, separate from the regular working berths of the ships. The extra time required to berth at such

[1] The General Manager, Maj. G. S. Sczlumper, contributes a description of these facilities in the *Dock and Harbour Authority*, April, 1923.

(*Courtesy, Mersey Docks and Harbour Board.*)

FIG. 193.—Port of Liverpool. The Prince's Landing Stage and Mersey River Bulkhead, taken from the deck of a liner at the stage, showing, from left to right, a baggage examination room, the Riverside Railway Station, the Royal Liver Building, the Cunard Building, and the head offices of the Mersey Docks and Harbour Board.

an ocean passenger depot would not take more of the ship's time than at present because the passengers are quickly landed and then left behind so that they are not in the way at the freight landing where the discharge of cargo can commence at once. The advertising the line will receive from handling passengers with this dispatch, and the comfort afforded them, will be a net gain. Also the union ocean passenger station of great beauty and convenience, while beyond the individual means of any but the very great passenger lines, undertaken as a port project serving all lines, would cost less per passenger than the present inadequate facilities of individual steamship companies.

(Courtesy of the Mersey Docks and Harbour Board.)

FIG. 194.—Port of Liverpool. Movable, half-portal, gantry gangplanks embarking passengers and baggage at the Prince's Landing Stage, taken from the deck of a liner at the Stage. Baggage belt conveyor in the foreground.

Prince's Landing Stage, Liverpool.—The oldest floating union ocean passenger station of this type is the Prince's Landing Stage at Liverpool. Liverpool is a wet dock port because of the variations in the tide of the River Mersey from 12 feet at neaps to 33 feet at springs. At ebb tide the current is as much as 7 knots. As far back as 1847, a floating landing stage was constructed. This was enlarged to over 2,000 feet in length and a width of 80 feet, in 1871, by consolidating various small stages. This stage was destroyed by fire shortly afterward and rebuilt in 1876. Additions have been made until it now has a length of approximately half a mile, 2,478 feet (Figs. 193, 194, 195, and 196).

The Prince's Landing Stage is carried on 200 iron pontoons, 80 feet long, 10 feet wide, and 6 feet deep, which serve as the foundation for the bridge-like structure that constitutes the deck of the landing stage. The

(Courtesy of the Mersey Docks and Harbour Board.)

FIG. 195.—The floating roadway or hinged ramp leading from the Prince's Landing Stage, Liverpool.

(Courtesy of the Mersey Docks and Harbour Board.)

FIG. 196.—Interior of the Riverside Railway Station adjoining the Prince's Landing Stage, Liverpool. Direct rail connection between ship and railroad.

deck is 6 to 8 feet above the water level. The pontoon is held in position by mooring chains and by bridges. These bridges are swiveled at the shore end while the deck end is moved on rollers in grooves on the float

deck. A number of foot bridges, each 110 feet long, connect the landing stage with the quay wall. One of the bridges located near the middle of the stage is 550 feet in length, 35 feet wide, and serves as a highway for wheel traffic as well as for pedestrians (Fig. 194). Upon the landing stage are erected light superstructures housing postal, telegraph, and telephone services, refreshment rooms, customs examination rooms, shipping offices, and the like. The stage is used annually by more than 6,000 ocean-going and coastwise vessels. The center portion opposite the highway bridge ramp is used for passenger and goods traffic across the Mersey River to Birkenhead. About 800 feet of this portion is set aside for passenger ferry service that totals about 28,000,000 people each year.

At the ends of the landing stage at which ocean-passenger traffic is handled exclusively, movable gangplanks, constructed on the principle of the gantry crane, quickly make connection with the side ports of the vessel at the various decks. Greater dispatch is achieved by using several side ports and gangways at the various decks of the vessel both fore and aft. In this way it is possible to accommodate first-cabin and second-cabin passengers at different ends of the ship, avoiding the slow process, experienced so often, of the entire passenger list in a single queue piling laboriously over one insecure and uncomfortably tilted gangplank.

The St. Pauli Landing Stage in Hamburg was obviously copied from the Prince's Landing Stage in Liverpool. It has functioned very successfully, although confined largely to the smaller types of vessels because the larger steamers land and receive their passengers at Cuxhaven at the mouth of the Elbe River.

The St. Pauli Landing Stage consists of one single platform 420 meters long (1,377 feet), 20 meters wide (65 feet 8 inches), carried by 109 iron pontoons each 20 meters long, 3 meters wide, and 1.9 meters deep (65 feet 8 inches by 9 feet 8 inches by 6 feet 3 inches). These floats were distributed at regular intervals, being closer together under the ramp bridges leading to the bulkhead. The landing stage has a mean draft of 1.10 meters (3 feet 7 inches), and the deck of the platform, a height above the water of 1.95 meters (6 feet 3 inches). There is a monumental passenger-station bulkhead house, which the landing stage parallels and with which it is connected by the ramp bridges. The head house contains ticket offices, baggage offices, rest rooms, waiting-rooms, restaurants, and offices.

Tilbury Landing Stage, at Tilbury docks, adjoining the Midway railroad station, there has been constructed, as part of the harbor railroad improvement, at a cost of a million pounds sterling, a floating landing stage 1,700 feet in length with 35 feet of water alongside at low tide. The object of this great investment is to give greater dispatch and more comfortable accommodations to passengers.

Volume of Passenger Trade.—The volume and trend of North Atlantic passenger travel may be shown by a few figures. These figures do not include travel to other ports of the world or southern Europe and give no indication of the great amount of coastwise passenger traffic. The White Star Liner *Majestic*, in 1923, carried 16,067 first-class passengers. The port of New York landed, in 1924, 365,133 passengers; of these 91,152 were first, 156,390 second and 116,805 third cabin. There has been a great increase in cabin passenger travel but a decline in third class and steerage. The lines have tried to overcome this by inaugurating inexpensive student tours, which are in fact excellent. Other decks are rigged to take passengers' uncrated automobiles. The more comfortable the tour, the more travel there will be.

(*Photograph by the author.*)

FIG. 197.—One of the several floating landing stages at the Naval Base, San Diego, California, for the accommodation of warship and private yacht tenders, "barges," gigs, motorsailors, etc.

Analysis of Principles Affecting Passenger-station Design.—With such migrations as these figures show, it is obvious that if a union ocean passenger station is built at a great passenger port like New York, the floating landing stage must be supported by adequate bulkhead passenger station structures. The floating landing stage corresponds to the concourse. As an aid in the calculation of such a marine gateway, a knowledge of the principles involved in railroad passenger station construction is essential as a basis. Railway station design has years of study and experience behind it. Ocean passenger stations have to date not been treated scientifically. This basis is given in an analysis of a report submitted by the committee on Yards and Terminals to the Annual Convention of the Railway Engineering Association.[1]

Port Accessories for Passenger Ships.—A passenger station for the dimensions of large passenger liners may or may not require certain

[1] Chicago, March 15, 17, 1923, and reprinted in the *Eng. News-Record.*

accessories peculiar to passenger travel, as all vessels of all lines touch at the landing stage for only an hour or so before proceeding to sea or to berth.

But eventual provision must be made at the permanent berth of the liner for all sorts of activities in connection with the operation of a passenger ship.

Laundry.—The last passenger and freight elevator job constructed by the writer in Bremerhaven just before the outbreak of the war was in a modern steam laundry for the terminals of the North German Lloyd. This was a modern plant that would do credit to a fairly large city. The size of the laundry problem from a great passenger liner possibly can be imagined by visualizing the accumulation of napkins, table cloths, and bed linen for hundreds and perhaps even thousands of passengers, from a voyage of 1 to 3 weeks. The Matson Navigation Company at its San Francisco pier has recently installed a laundry that takes care of the voyage wash between Honolulu and San Francisco. As the turnaround of the vessel is only 4 to 6 days, this laundry has a record of having put through 37,000 pieces of laundry in 4½ 8-hour days.

Cafeteria for Employees.—The Matson Company, on its wharf, has installed a cafeteria for its employees and its officers. Although this has no peculiar connection with the passenger traffic, it may be mentioned here that every well-equipped marine terminal must have proper facilities to give good food at low prices to its dock workers and to its other employees. In the port of Hamburg there are several coffee halls, many of which can accommodate as many as 1,000 dock workers at one time. There are separate dining-rooms for office personnel and for managers.

STEERAGE PASSENGER ACCOMMODATIONS

Whatever the immigration laws may be, next to exclusion such as that followed by the Chinese and Japanese for several years, there will be a necessity to accommodate steerage passengers both at the home and at the foreign ports to or from which the stream of immigration may be moving.

Too much has been said about Ellis Island, the Isle of Tears under the Statue of Liberty, to require further notice here. We can avoid the controversial subject by contrasting two classes of emigrants at the two principal European emigration ports before 1914, Hamburg and Bremen. This is in view of the fact that eventually selective immigration, to be successful, must be exercised at the port of embarkation abroad and not after the emigrants have squandered the savings of years in an effort to reach our shores. The two ports mentioned show a remarkable contrast. At Bremen there are no particular provisions for emigrant traffic except that the emigrants must get aboard the ship well in advance of the cabin passengers. How they get there is no particular concern of the steamship company. However, the poor emigrants, who become

the prey of money changers and cheap hotel proprietors, also are often looked upon as very objectionable and unornamental denizens of that city on and prior to sailing days.

Hamburg has followed a different policy, probably due to the fact that the late Albert Ballin started his career as a steerage passenger agent. This business he inherited from his father as a very young man. The old and conservative Hamburg-American Line discharged him as agent because he was too young, but later found it necessary to take him back into the company to save it from bankruptcy as a result of the young man's success in handling emigrants over other lines.

The policy of the Hamburg-American Line, under Albert Ballin's direction, was farsighted and enlightened. Emigrants were routed from their homes in Galicia, Russian Poland, Ukraine, the Balkans, and elsewhere to a large emigration camp. This camp was of a permanent character, built on the pavilion system with due regard to the religious requirements and racial characteristics of the people who were seeking new homes overseas. There were residence pavilions, pavilions with rooms for families, several kinds of churches such as Greek Orthodox, Roman Catholic, Protestant, Synagogues, and the like. Food was prepared according to the religious rituals of the various passengers. The entire cantonment served as a temporary internment for purposes of medical observation and political investigations and passport visas as well as a point of embarkation. Here shiploads of steerage and third-class passengers awaited the sailing date. This was not altogether a selfish policy on the part of the Hapag because quarantine detentions of ships or the return of rejected steerage and third-class passengers under American immigration laws were costly to the line. It is far less expensive to keep these passengers under observation, medical inspection, delousing, and wholesome feeding before sending them aboard ship than to have them rejected and returned after reaching the other side or to have the ship quarantined for days or weeks.

Undoubtedly American methods with regard to immigration must be changed and the American government should cooperate with the ship companies in establishing other such concentration camps abroad that will enable the blight of Ellis Island to be removed from the shadow of Liberty. Furthermore, efforts must be made to distribute immigration in the United States away from congested New York to such under-populated sections of the country as the South Atlantic and Gulf states. Proper study of the immigration problem, from the other end, should make it possible to divert and distribute our immigrants to those points where they are needed away from those points where they are now a great care and responsibility, not to say danger. At the same time, it is a more sensible and humane method of selective emigration if our laws be enforced at the source, the European ports of embarkation, rather than

after the damage has been done, when the poor creatures have arrived within our territorial waters only to find the savings, the dreams, and ambitions of years blighted by an exceeded quota or lack of knowledge of some of our restrictions, no matter how justified these restrictions may be in themselves for our own protection. So far as is known to the writer, the Hamburg-American Line emigration cantonment, across from the city of Hamburg, is the largest attempt that has been made to date to apply sensible methods in the handling of third-class and steerage passengers prior to embarkation.

The Compagnie Générale Transatlantique at Havre has a model embarkation unit in one large building. The nature of this equipment is seen from the illustration (Fig. 198).

(*Courtesy of the French Line.*)

FIG. 198.—The dining-room of the *Hotellerie des Emigrants*, French Line, Havre, France.

The number of individuals (whose comfort and health, as well as their right to life, liberty, and the pursuit of happiness) who are involved in the immigration problems of the ports of the United States and of the foreign ports from which they come, may be indicated by the fact that in 1907, 1,285,000 aliens were admitted, the greatest year. The year 1922 saw this figure reduced to 309,000 admitted and 199,000 leaving. All aliens do not travel steerage or third class, nor all American citizens in the cabin, but these exceptions about balance, and the statistics of immigration approximate third-class and steerage travel.[1]

In closing this chapter, it can be reaffirmed that the question of passenger traffic, both cabin and steerage, is in its swaddling clothes and offers one of the greatest fields for constructive thought in the entire category of port terminal development.

[1] From the *Wall Street Journal*, April, 1923, and reprinted in the "Port of New York."

CHAPTER XIV

BULK FREIGHT—ORE

ORE LOADING

The factors of transfer, transit storage, and warehousing are the same for bulk-freight handling as for package freight, but their applications are different for different products. The main warehouse or reservoir element in bulk freight is the stock pile. Likewise provisions for holding the cargo on the pier in readiness for quick transfer into the hold of the vessel are vital. The ore or coal pier looks very different from a general merchandise pier, but its function is the same. One difference between ore or coal piers and general cargo piers is that the former require different design according to whether they are to be used for loading or unloading. By the very nature of the traffic, the ore or coal movement over a pier is all in one direction. Loading and unloading require quite different equipment. Therefore, we have to consider: (1) the stock pile (warehouse); and (2) the loading pier, and unloading pier (transit wharves).

The return load factor has been a peculiarly fortunate circumstance in developing the Great Lakes traffic. Ore and grain come down the Lakes while coal goes up in about half the quantity down, thus partly balancing the round trip.

Special Carriers.—The needs of the heavy industries, which have grown to greater magnitude here than in any other country, coupled with the high wages prevailing, have developed not only the loading and unloading machinery but also the carriers. While the Mississippi River steamboat has remained unchanged, the lake barges have been transformed from the most inefficient form of water freight carriers to the most efficient (Fig. 202).

The usual Great Lakes carrier has a capacity of from 8,000 to 15,000 tons of ore or coal.

Record cargoes carried (to October, 1922) by lake freighters and the years in which they were made have been announced by the Lake Carriers' Association as follows:

Iron ore—14,137 gross tons, *W. Grant Morden*, 1920.
Soft coal—15,532¾ net tons, *D. G. Kerr*, 1919.
Hard coal—14,614 net tons, *H. G. Dalton*, 1920.
Limestone—14,084 gross tons, *D. G. Kerr*, 1918.
Wheat—503,156 bushels (15,095 net tons), *W. Grant Morden*, 1914.
Oats—760,066 bushels (12,161 net tons), *W. Grant Morden*, 1915.
Flaxseed—445,000 bushels (12,460 net tons), *Shenango*, 1916.
Rye—514,000 bushels (14,392 net tons), *Col. J. M. Schoonmaker*, 1922.
Corn—432,980 bushels (11,623 net tons), *The Harvester*, 1921.

Such records show what *can* be done but are not standard performance. However, the history of Great Lakes shipping indicates that the Lake vessels are increased in size and draft to take advantage of every inch of increase in the depth of connecting channels, locks, and harbors.

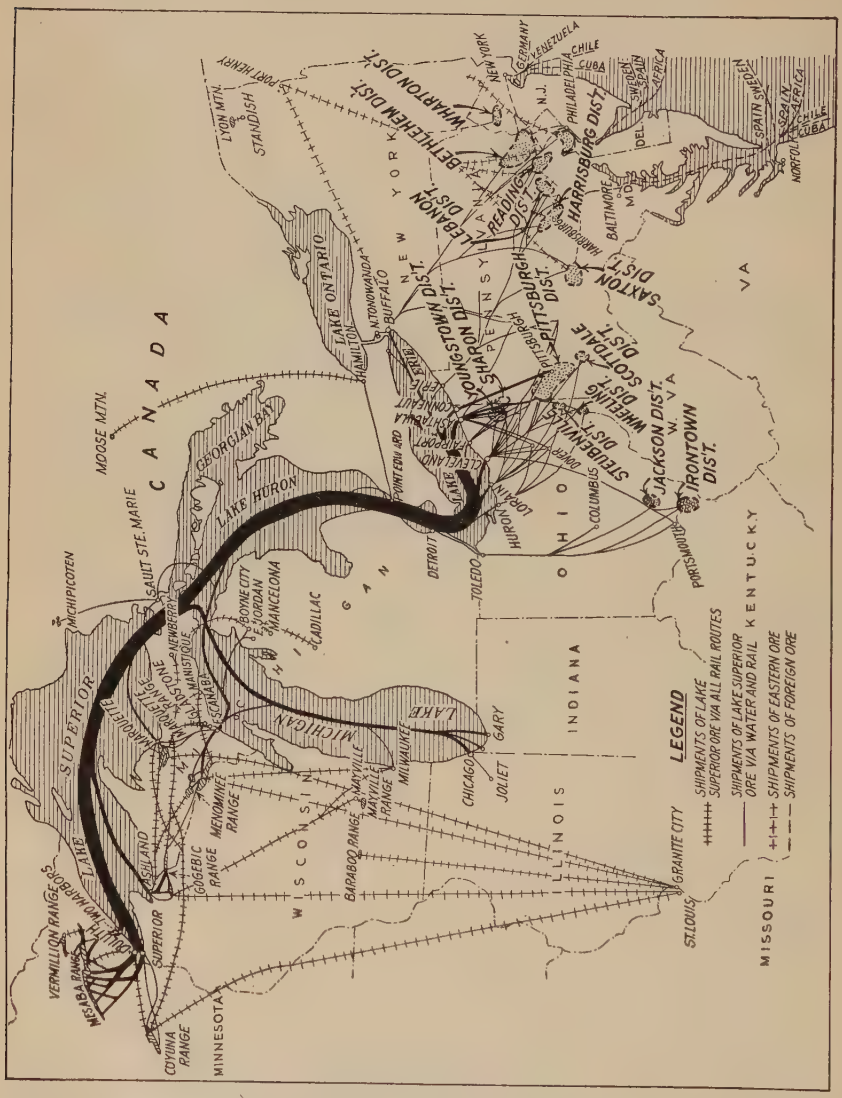


Fig. 199.—Map showing distribution of Lake Superior iron ores.

Harbor improvements from 18 to 20 feet depth were followed by a like increase in vessel drafts; then to 21 feet which is the present limit. Boats on the Great Lakes load to within 6 inches of channel depth and barely clear the bottom in the restricted channels. Each increase in channel depths makes possible greater draft and a larger and more economical

barge. Likewise every foot the water level of the Lakes is lowered costs the American and Canadian public many millions of dollars a year increased ton mile costs and subsequent pyramiding upon first costs.

A typical banner year of Great Lakes traffic was 1917 and the figures are attached for illustration. There have been fluctuations since, due to general post-war conditions. But there is every indication that these high totals will become normal averages as the country settles down to the new era. Inasmuch as the season of navigation is only about 7 months at the outside, the intensity of port activity during the season of navigation is almost double that of the same figures at an all-year ocean port.

Harbors	Order of tonnage	Harbors	Order of value
Detroit River	95,243,110	Detroit River	$1,269,690,776
St. Marys Falls	89,813,896	St. Marys Falls	1,196,922,183
Duluth-Superior	52,611,824	Buffalo	564,134,005
Buffalo	18,925,179	Duluth-Superior	471,309,736
Ashtabula	15,992,388	Milwaukee	362,564,868
Cleveland	14,282,687	Calumet	225,122,383
Toledo	13,710,238	Cleveland	128,239,054
Conneaut	12,956,398	Ashtabula	87,876,962
Agate Bay	10,773,241	Toledo	80,318,986
Calumet	10,269,304	Conneaut	62,501,557
Ashland	9,580,085	Agate Bay	43,020,032
Milwaukee	7,066,550	Ashland	36,137,511

The commerce at Detroit River and St. Marys Falls is practically all through freight.

The Newest Lake Type Bulk-cargo Vessel (to June 1924).—A vessel has been developed of the straight-line trough type, with high block coefficient, the forecastle, and navigation bridge far forward and the power units far aft. All the space in between is unobstructed hold. The hatches are separated only by the width of the thwarts which are spaced 12 feet between centers. The spacing of 12 feet is uniform on the Lakes and is almost as important as the standard gage of a railway. This type of vessel has a direct connection with the port facilities. All the loading bulk cargo, and the loading mechanism is designed for a 12-foot spacing. There are few bulkheads or compartments in the hold (Fig. 209). Sometimes there are as many as forty hatches but the usual number is between twelve and thirty.

More recent construction of lake vessels, illustrated by the *Henry Ford II*, have departed from the established practice of continuous hatches on 12-foot centers. The standard gage of multiples of 12 feet for carrier and pier has been maintained. It has been found, however,

that in loading vessels from ore pockets, as a rule, only every other chute has been utilized, and it has also been found that the new types of unloaders or unloading buckets can clean up at a considerable distance from the hatch opening. Therefore, the *Henry Ford II*, instead of having thirty-six hatches on 12-foot centers, has eighteen hatches on 24-foot centers. The advantage is on the side of economy and strength of construction. Furthermore, the movement from coal-burning to oil-burning and from oil-burning to internal-combustion (Diesel) engines has extended to Lake bulk freighters. The *Henry Ford II* is a motorship. As the last word, to date of writing, the characteristics of this latest type are worth including as another milestone in the progress of bulk-freight handling.

Motorship Henry Ford II.—This is a single-screw, steel-hull, Great Lakes freighter. Built as a motorship and commissioned in June, 1924. (Owners, Ford Motor Co. Builders, American Shipbuilding Co.) The sister ship, *Benson Ford*, was commissioned in July, 1924. (Builders, the Great Lakes Engineering Works.)

Hull		Engine	
L. O. A., feet	612	Built by Sun Shipbuilding and Dry Dock Co.	
L. B. P., feet	586		
Beam, feet	62	Name: Sun Doxford.	
Draft, loaded, feet	20	Type: Two cycle, opposed piston s. a.	
Gross tonnage	8,626		
Deadweight tons	12,000	No. of cylinders	4
Service speed loaded in statute miles per hour	13	Bore, inches	23½
		Stroke, inches	45½
		I. H. P. about	3,550
		B. H. P.	3,000
		R. P. M.	85

Auxiliaries: All, both deck and engine-room are electric drive, furnished by the General Electric Co.

Average fuel consumption in tons per day at sea estimated, 12.

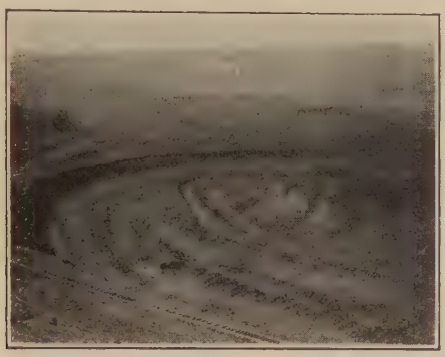
Average fuel consumption in tons per day in port, estimated, 1½.

Operated by the Ford Motor Co. in service on the Great Lakes carrying cargoes of lumber, ore, and coal.

Longitudinal Rigidity.—Discussions of the Great Lakes-St. Lawrence Ship Channel brought out the assertion that it was no use to open the Lakes to the Atlantic because the lake vessels of the long-trough barge type would break in two in the ocean waves and could never go out to sea. The assertion was based, first, on a false premise that the Great Lakes steel barges that handle bulk freight on the lakes would go to sea. This certainly is not to be anticipated, as their duties are well defined in the service which they perform on the lakes. On the other hand, recent calculations have been made that tend to show that the Great Lakes

freighter has approximately the same longitudinal rigidity as an ocean-going vessel.

Ore Loading Piers (Figs. 200 to 207).—The pier which has been developed to the highest degree and which is most generally in use is the trestle and pockets system. The narrow width compared to a general



(*Photograph by the author.*)

FIG. 200.—Ore handling. (1) At the mines the ore is loaded into 24-foot hopper cars by large steam shovels and the cars move in trains to the ore "docks"

merchandise pier shed is due to the fact that the material is stored vertically instead of being spread out on a floor. The pier carries a trestle 80 feet high with car tracks on the top; cars run from the storage pile or railroad yard over pockets on each side of the pier. The pockets are 12

(*Photograph by the author.*)

FIG. 201.—Ore loading. (2) Train loads of ore from the mines are run out onto the ore "dock" trestle, registering with the ore pockets or bins into which the ore is dropped. When caked, workingmen must dislodge the ore by means of long iron poles.

feet wide, and each has a capacity of five to seven 50-ton cars or 350 ton of ore. Ore cars 24 feet in length dump into two pockets. It will be seen that pockets, cars, and ship hatches are of corresponding dimensions and will therefore register. The pockets are loaded from the railroad storage yard or the storage piles by running the train of cars out onto

the trestle over the bins and dropping the ore through the bottom of the cars. If ore has been loaded damp at the mines and has caked, it is necessary to loosen it by hand. Working men, with long iron rods thrust through holes in the sides of the cars or from the top, keep the mass

(*Photograph by the author.*)

FIG. 202. —Ore loading. (3) Steamer (600- by 60- by 20-foot draft). *Emory Ford* enters her berth at ore pier, Duluth.

moving. In this manner, the "transit shed" is loaded directly from the cars, and holds the cargo awaiting the arrival of the vessel.

When the vessel arrives, it berths alongside the trestle. Its 12-foot hatches are all open and registering with the spouts of the 12-foot pockets or bins. These are lowered by electrical hoists operated by a mechanic

(*Photograph by the author.*)

FIG. 203.—Ore loading. (4) The vessel takes its position under the spouts. Hatches are opened.

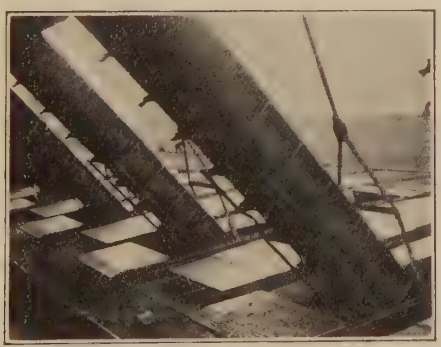
passing along the top of the trestle (Fig. 204). The sluices of the pockets are opened and in a very short time (23 to 45 minutes) the vessel is filled. The spouts are movable in a circle of a few feet to permit the material to be directed to all parts of the hatch; therefore, trimming is almost entirely eliminated.

The largest ore docks are located at Duluth, Minnesota. These docks (Figs. 200 to 207), four in number, project 2,304 feet into the harbor waters. They are equipped with 384 pockets each, a total of 1,536 pockets, with a gross capacity of 402,200 tons available for loading

(*Photograph by the author.*)

FIG. 204.—Ore loading. (5) The workingmen operate the electric lowering mechanism of each spout. He is lowering every other spout.

and storage purposes at this one point alone. Each pier affords berths for seven vessels. They are over 80 feet high, 60 feet wide, and carry four tracks each. All are electrically lighted and operated. When it is considered that there are at present a total of thirty ore-loading docks



(*Photograph by the author.*)

FIG. 205.—Ore loading. (6) The alternate spouts enter the vessel through alternate hatches. Spouts and hatches spaced 12 feet centers.

at Great Lake ports in the United States and Canada, having a combined storage capacity of 1,741,300 tons, some idea of the immensity of ore production and transportation may be obtained.

Ore Loading and Unloading Records.—The Great Lakes steel freighter, *D. G. Kerr,* one of the crack 600-foot long, 60-foot wide steamers

of the Pittsburgh Steamship Company, a subsidiary of the United States Steel Corporation, broke the world's record in loading and unloading iron ore. The *D. G. Kerr*, commanded by Capt. W. P. ("Speed") McElroy, is one of the fleet of 100 vessels of the company controlling the largest fleet of steamboats on the Lakes, and is one of the third largest boats on the Great Lakes. On Wednesday, Sept. 7, 1922, at the Two Harbors, Minnesota, docks of the Duluth and Iron Range Railroad, the *D. G. Kerr* loaded 12,382 gross tons of iron ore in 16½ minutes, or at the rate of 1,000 tons per 1.3 minutes, breaking the former record, which had stood for 10 years, made by the steamer *Corcy*, 9,362 gross tons in 25 minutes, at the rate of 1,000 tons per 2.7 minutes.

The *D. G. Kerr* docked at 5:42 p. m., started to load at 5:43 p. m., finished loading at 5:59½ p. m. and left the dock at 6:01 p. m. on her voyage down the lake. She was at the dock only 19 minutes.

(*Photograph by the author.*)

FIG. 206.—Ore loading. (7) The freighter loading.

The ore cargo was poured into the *D. G. Kerr* through thirty-five hatches, all hatches being in operation 2 minutes after the signal was given to start loading. No time was lost in trimming or balancing the cargo, the boat's hatches being battened down immediately after the lines were cast off, the automatic tell-tale registering exactly at zero, indicating the vessel was showing no list to either side. The draft of the steamer when loaded was 19 feet 11 inches forward and 20 feet 5 inches aft.

The loading was under the supervision of Captain McElroy, Dock Agent George Watt, and Mate C. A. Wallace. A newspaper man on board of the *D. G. Kerr* was the official timekeeper.

When the cargo reached the company docks at Conneaut, Ohio, on Sept. 12, another record was broken in unloading, the 12,382 gross tons being unloaded in 3 hours and 5 minutes, at the rate of 1,000 tons every 14.9 minutes, against the previous record of the steamer *McGonagle*, made in 1919, of 14,269 tons in 12 hours and 25 minutes, at the rate of 1,000 tons every 52.2 minutes, and the steamer *P. A. B. Widener*, made

in 1912, when, 10,636 tons of ore were discharged in 2 hours and 50 minutes, at the rate of 1,000 tons every 16 minutes. The *McGonagle* and *P. A. B. Widener* also unloaded at Conneaut.

ORE UNLOADING

Unloading has not been brought to the same degree of speed as loading. Loading is an affair of gravity. Once cars are pushed onto the 80-foot high trestle, the further operations are only the controlling of the gravity feeds. However, when unloading, until there is a ship dumper designed which will lift the ore vessel and turn it over and spill out the cargo, as is now done with a 100-ton car, there must be designed ever more efficient and rapid systems of elevating machinery. The improvements which have been made in 30 years have cut the cost of discharging an ore

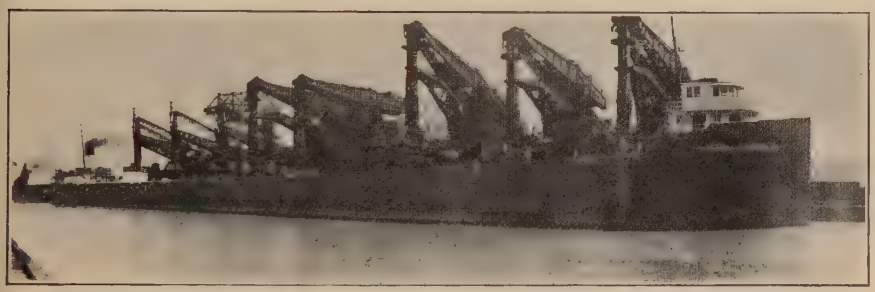


FIG. 207.—Battery of nine ore unloaders working on a large ore carrier.

ship from 56 to 4 cents per ton. The history of this achievement by one who has lived through the period of its development was given by Mr. Carey at the Cleveland meeting of the Association of Port Authorities. In substance he gave the following account:

Development of Bulk Unloading.—In the early eighties two methods were in common use to unload ore: (1) with a horse and block and falls, hoisting about one-half of a ton of ore in a bucket through the hatch to the height of the runways, where two men would drop it into a barrow and one wheeled it to the "dock;"[1] (2) with an engine with drum and three falls, arranged to hoist all at once from three different hatches.

Next came the McMyler whirler, a revolving jib crane, which lifted a 1 ton bucket of ore from the ship to the car or "dock." It was a revolving derrick, and had two buckets. As one was being loaded by a shovel in the hold, the other would ride up above the deck. When the volume of ore began to increase and the necessity of stock piles became imperative, Alexander Brown evolved the Brown Hoist and Bridge.

[1] On the Great Lakes the word "dock" is a localism, always used to mean some kind of a wharf and not the water beside the wharf.

This mechanism contains three machines which travel along a rail on the front wall of the "dock," and on a back rail in the rear of it. Practically bridging the space between the two, extending arms come out along

(Courtesy of the Wellman-Seaver-Morgan Co.)

FIG. 208.—The open bucket of a 17-ton unloader descending through the hatch of a modern lake freighter carrying ore. The position of the operator, who travels in the leg of the unloader just above the bucket, from which position he can see every operation and be independent of signalmen, is clearly shown. The spread of the bucket is 22 feet.

which the buckets run on a carrier to the ore pile or unloading cars where they may be needed. This new device cut in two the cost of depositing the ore in the stock pile, as well as saving much of the time required.

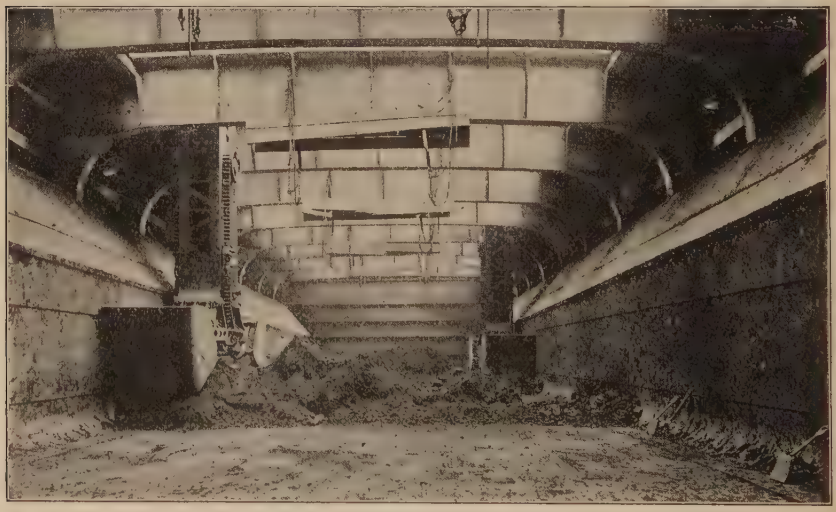


FIG. 209.—Leg of Hulett unloader in the hold.

The next improved device, the one which is in general use today, is the Hulett "grasshopper" unloader. Beginning with the idea that the use of the hand-operated shovel would have to be eliminated in order to

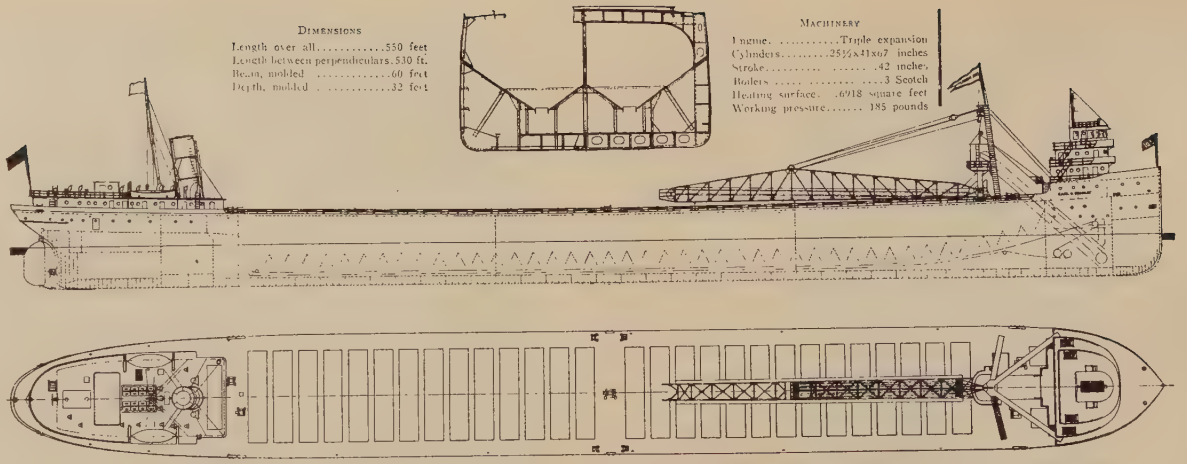
gain any material increase of speed, Frank E. Hulett in 1898 perfected a line bucket which was to sink its cutting jaws, while open, into the ore to the depth of about a foot, and then come together on a plane surface.

The "grasshopper," which is now in wide use, consists of a massive frame, or walking beam, whose front end rests on the face of the dock and the rear end on a slightly raised concrete wall (Fig. 207). On this frame is a carriage moving backwards and forwards over the ore trough. At the outer end of the walking beam we find the legs, which reach down into the hold. Figure 207 shows an installation of nine unloaders at one berth, constructed by the Wellman-Seaver-Morgan Company of Cleveland, Ohio. The whole mechanism is operated by one man who travels in the vertical leg (Fig. 208). Underneath the main frame and running along the bottom are the weighing hoppers. When a load of ore (15 to 20 tons) is elevated by the bucket clear of the vessel, the carriage runs back on the main frame until the bucket is over the weighing hopper or the ore trough, and there the load is released. The weighing hopper moves only between the main legs of the machine. A cable runs alongside of each track continuously, and the movement of the cars is taken care of by the cable. An operator pulls a lever on the mechanical clamp which is attached to the train and moves the car or the train half a car length for the next load. The stretch of the buckets when they are open is about 22 feet, and they carry a load of from 15 to 17 tons. They average about 45 seconds to the load.

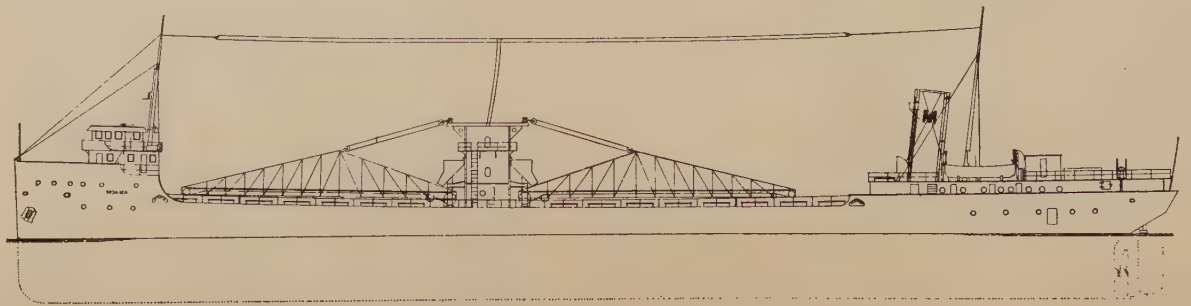
The cheapening of the cost of unloading by the successive steps by which the process was improved between 1880 and the present may be shown by the following comparison:

Cost of unloading a ton of coal with barrows.	56 cents
With Brown machine and shovelers	28 cents
With Brown fast plants	12 cents
With Hulett fast plants	4 cents

Self-unloaders.—A type of Lake boat has been developed which is fitted with mechanical equipment for unloading its own cargo. The advantage of this boat is that it can call at ports not fully equipped and unload small or large amounts with its own equipment at a very low cost. The first self-unloader built by the Great Lakes Engineering Works in 1907 was 286 feet long, 45-foot beam, 24-foot molded depth designed to carry 3,300 tons of stone on a 15-foot draft. One boat built by the Great Lakes Engineering Company for the Wyandotte Transportation Company about 1915 will serve as an earlier example. She is 439 feet long overall, 56 feet beam, has 21 hatches, and will carry from 6,000 to 8,000 tons of cargo at a speed of 12 miles an hour. Inside she is built with two long hoppers in the shape of a flat "w" with the sides at an angle of 35 degrees. Under the two lower points of the "w" are two



General arrangement of self-unloading steamer Carl D. Bradley, built by American Ship Building Company; capacity in stone, 12,000 tons



(*Marine Engineering and Shipping Age, February*, 1925.)

FIG. 210.—Outboard profile of projected ship of about 6,500 tons deadweight fitted with double booms.

42-inch pan conveyors. These conveyors move the material forward. At the bow the conveyors rise and discharge into a cross-chute which itself discharges into a 42-inch discharging conveyor boom with a radius of 67 feet. This conveyor will pile the material 52½ feet from the sides of the ship at an angle of 90 degrees. The mechanism is driven by two 150-hp. engines. Such a boat can discharge at any place where there is a wharf for a minimum cost at the rate of 600 to 700 tons an hour.

As in other Lake bulk carriers, the later models show much progress in refinements of detail and notable increase in both size and performance.

(*Photograph by Robins.*)

FIG. 211.—Conveyor boom of a modern self-unloading bulk freight carrier on the Great Lakes.

An example of the 1925 model is the steamship *Carl D. Bradley* (Figs. 210, 211), built by the American Shipbuilding Company with a capacity of 12,000 tons, length overall 550 feet, beam 60 feet, molded depth 32 feet, loaded draft 20 feet.

The rate of discharge has gradually increased from 800 tons an hour to 2,000 tons an hour. To increase the rate of discharge, models are projected with two conveyor booms located midships.

It will be apparent that the self-unloader has less cubic and greater displacement light than the usual bulk freighter. The advantage to offset this lower lifting efficiency is the time saved in port and complete independence of shore equipment, labor, fixed hours, and the earning of unloading rates otherwise collected by operators of shore equipment. The ability to make delivery at any point where the vessel can tie up alongside makes much more business possible. Such business is, to use a railroad term as a simile, local station business and, therefore, due to

lack of competition, pays a higher rate. Furthermore, such a vessel is best in short leg voyages because of quick turnarounds. "One of these vessels has handled 110 cargoes in a season of 240 days, taking stone in one direction and coal in another, frequently three cargoes in a round voyage."[1]

Unloading Ore from Ocean Steamer.—The importation of ores from Cuba, Spain, Northern Africa, and Sweden is increasing. Therefore, this movement is coming more into evidence. An example of an apparatus for unloading from ship to cars is the McMyler unloader at the Girard Point Terminal of the Pennsylvania Railroad, Philadelphia. The machine consists of a tower 96 feet high. The base is a full gantry spanning two railroad tracks. Forty-nine feet above the level of the wharf is the track on which the grab or scoop buckets of 3 and 2 tons capacity, respectively, work the cargo from ship to hopper. The buckets travel along a track one-third of which is built solid in the tower. The remaining part is a movable boom which is hoisted to a vertical position to avoid fouling the tackle when moving the ship. The hopper which feeds the ore into the hopper cars acts as a reservoir. The boom-and-hopper principle is a usual arrangement for all bucket and transfer track installations. This one has a reach of 45 feet beyond the face of the wharf. The capacity at 120 cycles an hour, a round trip every 30 seconds, is 200 tons.

The problem of unloading the ore from ocean steamers is complicated by the greater depth of the hold and the smaller number of hatches. Ocean bulk freight carriers in the past have been, as a rule, ordinary tramp ships, and no particular provisions were made toward cargo specialization as has been the case on the Great Lakes. One of the most active ports in the foreign ore trade is that of Huelva, Spain. The exports of iron pyrites ore from the province have averaged 2,000,000 tons annually for the last 10 years. Also large quantities of copper pyrites or chalcopyrites have been exported. There are a number of long trestle piers, the principal one being the Rio Tinto Pier at Huelva, the ore cars dropping their contents into hoppers, the ore being conveyed over the hatch of the ship into which it is fed by electric belt conveyors.

Other important iron ore ports are Narvik in Sweden, Cienfuegos in Cuba and several along the coast of Africa.

The Bethlehem Shipbuilding Corporation plant at Sparrow's Point near Baltimore, Maryland, using Cuban ores, has been developing special types of carrier, somewhat similar to the Great Lakes ore carrier, but with higher freeboard, less length, and carrying a series of short masts on the deck to handle the ore with ship's tackle. This company (Sept. 12, 1921) inaugurated the combined ore and oil vessel, the *G. Harrison*

[1] Penton, Henry, and Sadler. Professor Herbert C. Sadler before the Society of Naval Architects and Marine Engineers, New York, November 1924.

Smith, and on Feb. 11, 1922, the steamship *Bethore* of 20,500 tons capacity (Fig. 212). This vessel is so built that it can carry oil in one direction, for instance, to Spain or Sweden, and return with a cargo of ore, thus giving a cargo both ways. The ore holds occupy space 30 feet wide by 30 feet deep for a distance of 360 feet through the hull of the vessel, and are elevated 14 feet above the keel, the remainder of the vessel being an oil space. All hatches are 30 feet wide and full width of the ore hold. The rigging consists of ten masts, or king posts, carrying eighteen 36-foot Oregon pine booms of 3 tons capacity each.

This equipment is to take care of general cargo and ore at ports where there are inadequate terminal facilities. Estimate at an equipped terminal operating two 15-ton grab buckets is a complete discharge of the ore in 40 hours.

The older type of ocean bulk carrier for ore or coal, as in the case of colliers of the United States Navy, differ little in outward appearance

FIG. 212.—Steamship Bethore ready for her trials. Twinscrew combination ore and bulk oil carrier.

from the combination carriers just described. The double rows of masts carrying bucket tackle are characteristic of these. These vessels are familiar sights in such ore-importing ports as Rotterdam or Baltimore. A collier of this type carries coal or ore or similar bulk commodities, as the service demands.

Unloading Rigs for Other Bulk Commodities.—Although the principal bulk commodities of a rough nature are ore and coal, similar equipment will handle such other commodities as phosphate rock, nitrate in bulk, chalk, kainit, kali or potassium salts, kaolin or clay, rock salt, etc. The difficulty in handling these latter products over a coal or ore wharf is the difficulty of sufficiently cleaning the equipment to avoid contamination to the other products. Coal will not improve chalk, and, in particular, nitrates once handled over a terminal will make it very difficult to handle salt.

Also these commodities do not move in quantities sufficiently large to carry the overhead of the same heavy-duty equipment. The lighter-duty rigs such as shown at Duluth to unload limestone for the steel plant at Morgan are the usual equipment for this traffic (Fig. 213).

The Stock Pile Functions as a Bulk-storage Warehouse. *Coal Reservoirs.*—The need of reservoirs for bulk commodities, in particular for coal, to tide over any interruption in the usual course of transportation, has been brutally brought to the attention of the people of the country, especially of New York, from time to time. The coal situation is an acute manifestation of the necessity of reservoirs in the movement of all commodities. The lack of this provision is one of the prime causes of freight congestion and car shortage. The country has been accustomed to live from hand to mouth in transportation matters. When the railroads brought more to the seaboard than the ships could take

(*Photograph by the author.*)

FIG. 213.—Unloading rigs for limestone at Duluth. Limestone is destined to steel plant at Morgan, the stone being a return cargo for ore carriers. This is a characteristic rig at tidewater and on the Lakes for commodities other than ore or coal, that are not moved in volume that will justify the heavier equipment used for the chief bulk commodities.

away, having no warehouse provision to stabilize it, the transportation of the country was upset. There were no buffers, no springs, no flywheel to take up the thrust of the irregularity. When the cold days came and the coal cars did not move as usual, with the blocking of cars for the lack of warehouses to hold other commodities, there ceased to be the regular stream of coal moving to the city. There is no stored-up energy of supply which would carry the city over the dead center of traffic disturbances. The transportation system has been run on the principle of a 1-cylinder motor without a flywheel. As long as it has full gas, it sputters along, but let it miss fire a time or two and it stops dead.

The stock pile serves as the warehouse reservoir for bulk materials. Coal, ore, gravel, sand, broken stone, and some other materials come onto stock piles for storage. The most important commodity is coal

and then comes ore. All other materials are decidedly secondary in importance. Back of an ore- or coal-loading trestle pier is track room for the storage of cars and often a stock pile. At the point of unloading from boat to land is a stock pile. Car storage is not often found as an essential part of an unloading layout, although in loading trestles car storage is most important.

In the movement from mine to boat on the Lakes, because navigation is closed for such a long time, the reservoir in the upland back of the loading piers must be exceptionally large. Sometimes as much as 4,000,000 tons of ore must be held there before the opening of navigation. This would require 40,000 cars. Much of it is held in cars, but obviously car storage will not do for the entire amount. The stock piles in the upland behind the pier must be the main reservoir in addition to many miles of railway yards. The entire problem of car dumping, piling, and retrieving has developed much invention. As a rule it is the best policy to have the largest reservoir at the mine and keep the cars moving the material to the loading pier when navigation opens.

The usual unloading movement of bulk materials is from the steamer to the stock pile of a steel mill or large power plant. The steel mills are the greatest consumers of bulk materials and must be absolutely assured of their supply of ore and coal for the period of closed navigation. Both the warehouse and the wharf principles are involved, although at first it may seem that the "transit shed" has been eliminated. The two movements are more distinct because the bridge tramway serves the warehouse stockpile, and the Hulett "Grasshopper" unloader plays the rôle of the pier shed and crane on the wharf front. Whether the movement from steamer to stock pile be over one bridge or over an unloader and a bridge, it is still quite necessary, in the interest of speed in unloading, to get the ore out onto the nearest spot as fast as possible. Therefore just back of the waterfront there is a small transit pile which accommodates the cargo of one or two boats. It is then necessary to rehandle this material in removing it to a large stock pile farther back where it remains until recovered for use in the plant. The second pile is the warehouse and the first the transit wharf. There is no getting away from this double handling of the major part of the cargoes unloaded during the period of open navigation.

An example of the application of continuous motion in bulk-freight handling is shown in the Stuart System of Ground Storage.

Stock Pile Foundations.—The technical difficulties of the stock pile are greater than they would seem at first. An example of the problems involved, from the engineering point of view, may be gleaned from a bulletin of the Cleveland Dock Engineering Company. The stock-pile floor in point was built for the Detroit Iron and Steel Company, and is of particular interest because the plant and the stock pile are built on

reclaimed marsh land. The pile is built "on a wet sponge." The utilization of marshy land for industrial purposes is of much interest because the future of scientific harbor building in the United States will have to do with reclaimed land. Reclaimed marsh land usually is the

FIG. 214.—This shows the way the timber docks fail. The weight of the ore forces them outward and upward.

only land properly located for municipal harbor works which does not require a prohibitive amount of expropriation of existing owners.

The wharf in question consists of two parts, the wharf apron and the stock-pile floor (Fig. 214).

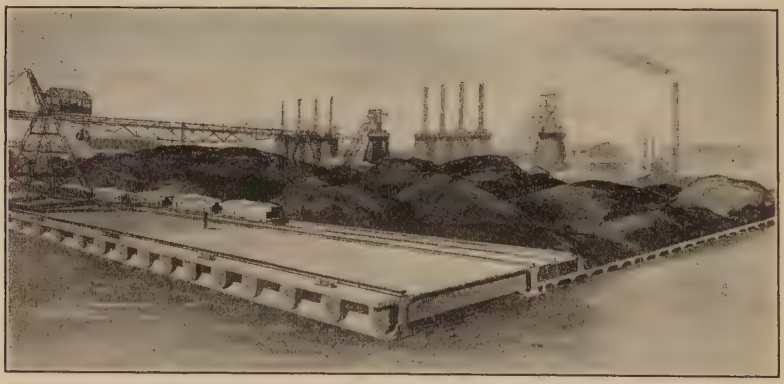


FIG. 215.—A perspective showing clearly the arrangement of dock girders and ore floor in the Cleveland dock built for the Detroit Iron and Steel Company.

The site of the proposed wharf and pile (they call it an ore "dock" on the Lakes) was low-lying marsh, often ½ foot to 2 feet under water. The problem was to build a platform on this sponge which would carry a load of 7,000 pounds per square foot, put upon it by the mountains of ore. The ore floor, 173 feet deep, is a reinforced concrete mat 1 foot thick, resting on piles driven 5 feet on centers in both directions. Con-

nected to this floor and forming an integral part of it is the wharf apron extending over the water to deep water. This consists of two massive reinforced concrete longitudinal girders, 9 feet high, the bottom flanges being 5 feet wide and the webs 16 inches thick. The top flange of the outward girder is extended outward as a 10-inch bracketed shelf, shoreward as a 6-inch floor to the other girder. Supporting this floor and tying the girders together are concrete beams, 10 feet on centers, 10 inches thick, and 5 feet deep. By giving the stock pile full support the tendency to force the mud out from under the load and upwards at the wharf edge, thus completely deforming the wharf front and unloading bridges, has been eliminated (Fig. 215). There have been conspicuous failures of unloading wharves where the stability of the bearing surface of the stock pile was not provided for. The illustration serves to show that, by building properly, many acres of marsh land at present valueless may be made into the most desirable industrial harbor areas.

CHAPTER XV

BULK FREIGHT—COAL

COAL LOADING

Coal is shipped in great quantities. It has been the backbone of British shipping supremacy. For decades exports or coal in cargoes have assured British ships an outbound load. The control of fuelling stations for ships, scattered thickly about the world, gave the British shipping men control of the world's steamship business, as demonstrated before the United States entered the war when the British fuelling control made it possible to dictate to neutral shipping.

Progress in handling coal by mechanical means has been great, but this progress has been greatest on the Great Lakes where coal forms an important return load, equal almost to half the down Lake bulk movement. The entire Northwest is provided with fuel from Pennsylvania carried in the same bulk freighters that load ore and grain down. As in the case of ore handling, the coal-handling appliances for loading and discharging have reached a high state of perfection. The knowledge gained has been applied also to export coal at tidewater.

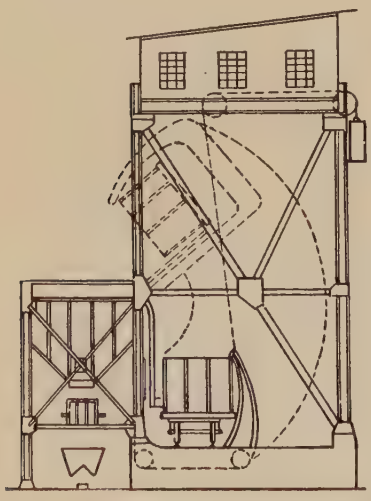


FIG. 216.—Sketch cross-section of the car dumper.

Distinction between Cargo and Bunker Coal.—Coal is loaded for cargo and for bunkers. There are deep-hold vessels and shallow-hold vessels. Equipment has developed to meet the needs of all of these services. A rigid distinction should be made between loading and discharging cargo coal and bunkering, the supply of fuel to ships, to be consumed on the voyage. At a busy export cargo coal pier, there is no time for bunkering operations, therefore, loading cargo coal and bunkering operations should be considered separately.

The first element in modern coal loading is the car dumper or tipple. To this car dumper various refinements have been applied to prevent coal from breaking when dumped into deep-hold vessels, for trimming and for increased speed in loading.

Car Dumpers and Deep-hold Ships.—For shallow vessels the pan is sufficient, but to load cargo coal in ocean-going vessels requires some form of "lowerator." Such a combination of dumper and lowerator is shown in the type installed at the Southern Railway Coal Pier (Fig. 217). In this type the car-dumper tower travels along the main or elevated portion of the pier while a second tower, moving with it, travels along a lower level wharf. This second tower carries a lowerator, a hopper, and a conveyor arm with a vertical leg. A belt and bucket conveyor moves the coal from the hopper and lowers it into the hold. As the vertical arm is pivoted, much trimming is obviated by loading directly into the wings. The tipple moves along the wharf from one

(Photograph by Melcher.)

FIG. 217.—The coal tipple with automatic trimmer for loading cargo coal into ocean ships and for bunkering, Charleston, S. C.

hold to another. This is an economical layout for a coal-loading rig of moderate capacity.

The car dumper (Figs. 216 and 217) in some form is the basis of coal loading. It is a mechanism that lifts an open-top car loaded with coal and turns it over. A modern car dumper will handle fifty 50-ton cars of coal an hour. From the car-storage yard the cars roll down to the barney pit by gravity. The car is then engaged by the barney and drawn up the incline to the platen or dumper platform where the car is clamped to the cradle. The cradle is then raised and turned over through an arc of 160 degrees, dumping the coal into a pan. The empty car is revolved back to its normal position, loosened, is pushed off by the next car coming up, and runs down an incline to a kickback that sends it by gravity to the empty yard. The pan containing the coal is lowered,

when full, and from an angle of 50 degrees the coal slides, but does not drop as that would break it, into the barge or hopper or pocket or conveyor.

Operating Costs of Various Types of Coal-handling Equipment, both Dumping and Recovering.—From a recent paper on the subject[1] the following types of equipment with costs of operation have been tabulated:

	Capacity, 8-hour day, tons	Cost per day operation	Cost per ton	Size of bucket, cubic yards
1. Revolving Locomotive Crawler Tread Crane (Caterpillar)	400	$ 29.75	$7.44	1
2. Revolving Locomotive Standard Gage Crane	600	41.37	6.89	1½
3. Revolving Locomotive Wide Gage Crane	1,500	68.50	4.56	5½
4. Electric Bridge Tramway Crane	3,500	213.50	6.09	12
5. Car Dumper and Transfer Car	4,000	100.00	2.86	

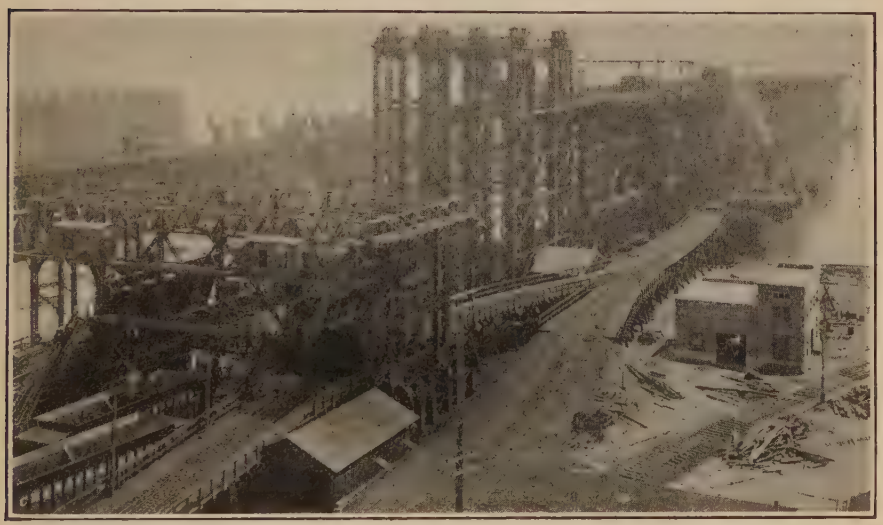
The Stuart System of Export Coal Piers.—Perhaps the largest export coal pier yet constructed is the one of the Baltimore and Ohio Railroad at Curtis Bay, Baltimore. This is of the Stuart system of continuous motion by belt conveyors and is revolutionary in the results obtained. This pier has a capacity of 12,000,000 tons a year, whereas the maximum capacity of the old pier is 2,500,000 tons.

Beginning at the land end, the installation consists of a hump classification and car storage yard, a thawing house with a temperature of 180 degrees which will thaw a frozen car in 30 minutes, and then two car dumpers of the familiar McMyler type. Each car dumper will handle fifty 50-ton cars per hour. The pan containing the coal is lowered when it has received its full capacity of 120 tons. From an angle of 50 degrees the coal slides, *but does not drop, as this would break the coal,* into a hopper which feeds the coal to belt conveyors. Each hopper feeds three belts through three separate feeders. Two of these belts go directly to the pier. One goes to two balancing and two trimming bins with 1,500 and 1,000 tons capacity, giving a total capacity of 5,000 tons for this reservoir. This balancing bin is an excellent example of the reservoir principle. It is to take up the slack in the intermittent movement of cars and the loading process. Hoppers from the car dump, and 48-inch and 60-inch belt conveyors, from the trimming and the balancing bins run out onto the pier to the loading towers. By means of a system of elevating,

[1] Titcomb, George E., in a paper before the Metropolitan Section, American Society of Mechanical Engineers, 1925. "The Application of Various Types of Coal Handling Equipment."

lowering and trimming belts coal is uniformly stowed without at any time dropping and breaking it.

There are four loading towers and two trimming cranes on the pier to load two large colliers simultaneously, that is, two complete units throughout. The point to be reiterated is, that by means of belts and bucket lowerators a continuous motion has been accomplished, insured by the balancing bins which take up any unevenness. The capacity attained is astounding. At a normal operating capacity the old trestle, working seventy-five men, could load a 7,000-ton vessel in 7½ hours.



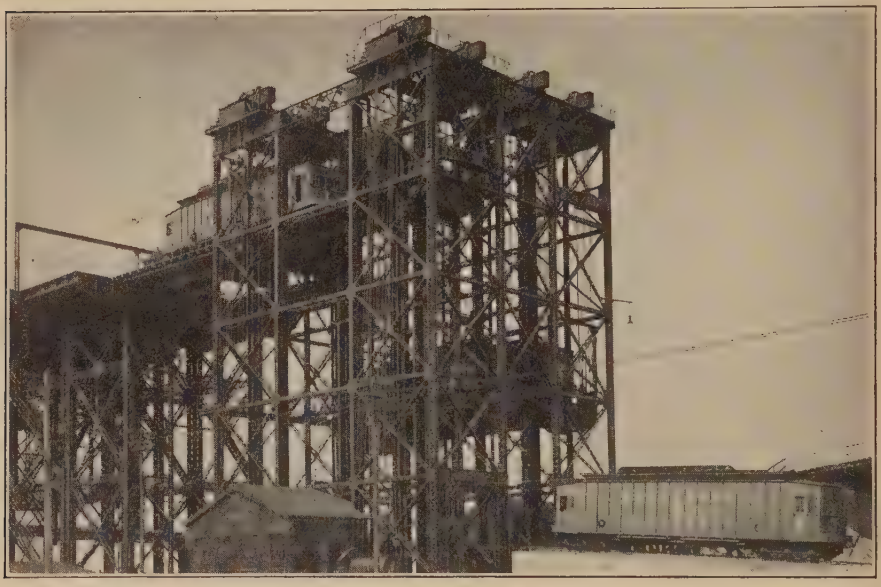
(*Courtesy of Wellman-Seaver-Morgan Co.*)

FIG. 218.—System I. Export coal piers at Newport News for the C. & O. Railroad and at Norfolk for the N. & W. Railroad (identical installations). After the coal has been dumped from the road cars by the usual automatic car dumpers into transfer cars of special design, these transfer cars are elevated to the top of the pier trestle. The speeds of the elevator are so regulated that each side will handle thirty transfer cars the hour. The loaded transfer cars weigh about 350,000 pounds or 175 tons.

With twelve men, the new pier operating only one unit (half pier) will do the same work in 3 to 3½ hours. With only one unit of the pier in operation it has happened on several occasions that 165 cars arrived at the same time as a vessel. In 8 hours they had been unloaded and assembled in trains, and were on their way back to the mines for more coal. The actual loading and bunkering of the vessel with the contents of 165 50-ton carloads of coal required less than 4 hours.

Hampton Roads Export Coal Piers.—The export coal-loading piers of high capacity and great speed at Hampton Roads are very similar to the ore "docks" of the Head of the Lakes, in the general principle involved. At Lake Superior ports the shores rise abruptly from the water, and the rails from the mines come down over the hills and run directly to

the top level of the trestles. At tidewater it is necessary to raise the cars themselves, or raise a shuttle car into which the coal is dumped, to the top of the trestle. There are two systems, similar in outward appearance when viewed in passing, but quite dissimilar in operation. Pier No. 1, Virginian Railway (also Norfolk and Western Railroad and Chesapeake and Ohio) 1918 model, uses the system of transfer cars, elevated to top of trestle, dumping into bins that load the ships by gravity through chutes in the bottom of the bins (Figs. 218 and 219).



(*Courtesy of Wellman-Seaver-Morgan Co.*)

FIG. 219.—System I. Export coal piers of the C. & O. Railroad, Newport News and of the N. & W. Railroad at Norfolk. In this installation the same principle is followed as in the great ore trestles at the head of the lakes except that the coal is dumped from the road cars to a shuttle or transfer car which is elevated to the top of the trestle.

On Pier No. 2, Virginian Railway, 1925 model, F. F. Harrington System, the coal is elevated by an elevator car, dumped at top of trestle into a conveyor car that dumps into the hopper of a traveling telescopic spout and mechanical trimmer.

1. *Description of Coal Pier No.* 1, *Model,* 1918.—Additions to the coal-handling equipment of the Virginian Railway Company at Sewell's Point, Virginia, recently completed, include a double car dumper, six 120-ton transfer cars, and a transfer car elevator. The contents of road cars, brought loaded from the mines, are dumped into the transfer cars. These are taken by the car elevator to the loading pocket on the pier, where their contents are dumped, afterward to be discharged through chutes into ships lying alongside the pier. About 4,000,000 tons of coal are hauled each year over this pier.

The double car dumper can overturn two ordinary road cars at once, the first machine of its kind to do so. It can handle two 60-ton cars or one 110-ton car. The main frame supports a rotating cradle, which holds the cars. In the bottom of the cradle are rollers that support a movable platen. This carries the car rails. The roller rotates about pivot pins, which are carried in heavy pivot frames built into the main framework. Eight automatic clamps hold the cars in place. These clamps are operated independently by counterweights and are so placed that they engage different lengths of cars.

Dumping two cars at once necessitates wide clearance between the front posts 94 feet center to center and 91 feet 8 inches clear dumping space. Coal dumped from two cars, end to end, is spread over about 88 feet. Inasmuch as the hopper of a transfer car is 51 feet, and in order to discharge all the coal from the two road cars into the transfer cars without a concentrating chute, two steel apron conveyors, 24 feet by 8 feet supported horizontally in a portal frame, are provided. A clear space of about 36 feet is left between the conveyors, which form a portion of the bottom of a hopper into which the road cars are dumped. All the coal thus is transferred horizontally and discharged, obviating the drop of a concentration chute, the complete cycle requiring 2 minutes to dump a car or pair of cars.

The transfer cars are self-propelling; trucks spaced 50 feet center to center; total length over all, 70 feet; height, 16 feet; width, 12 feet. The body of the car is a hopper divided into three compartments, each having a 40-ton capacity. Each compartment has a double system of discharge gates at the bottom. The combined weight of car and contents is about 400,000 pounds. These cars are the largest coal transfer cars ever built.

When the transfer car has been loaded it moves 500 feet to the elevator, is lifted 65 feet to the elevation of the top of the pier, moves along the top to above the bin, and is discharged.

2. *Description of F. F. Harrington System Virginian Railway, Coal Pier, No. 2, Model,* 1925 (Figs. 220*a*, 220*b* and 221).—Coal Pier No. 2 is located on the south side of the present coal pier and is approximately 1,074 feet long, 86 feet wide, and 74.5 feet high above mean sea level. The distance between center lines of piers will be 397 feet and will provide a slip of 319 feet. The foundations will be constructed to provide for a depth of water alongside the pier of 40 feet below mean low water, but the slips and approach to the channel will only be dredged to a depth of 35 feet below mean low water at this time.

The pier consists essentially of a steel superstructure supported on cylindrical concrete foundations, two elevating car dumpers with haulages, each to handle one 120-ton or two 65-ton coal cars, one elevator located between the two car dumpers for taking empty conveyor cars to and from top of pier for making repairs, four traveling loading towers

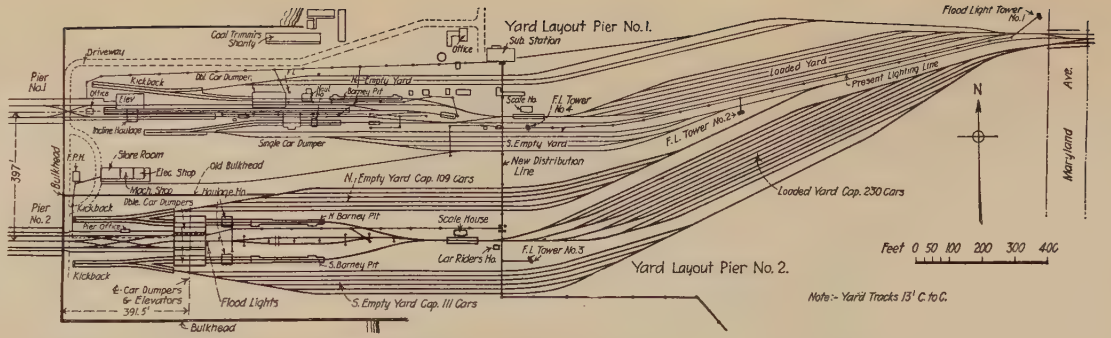
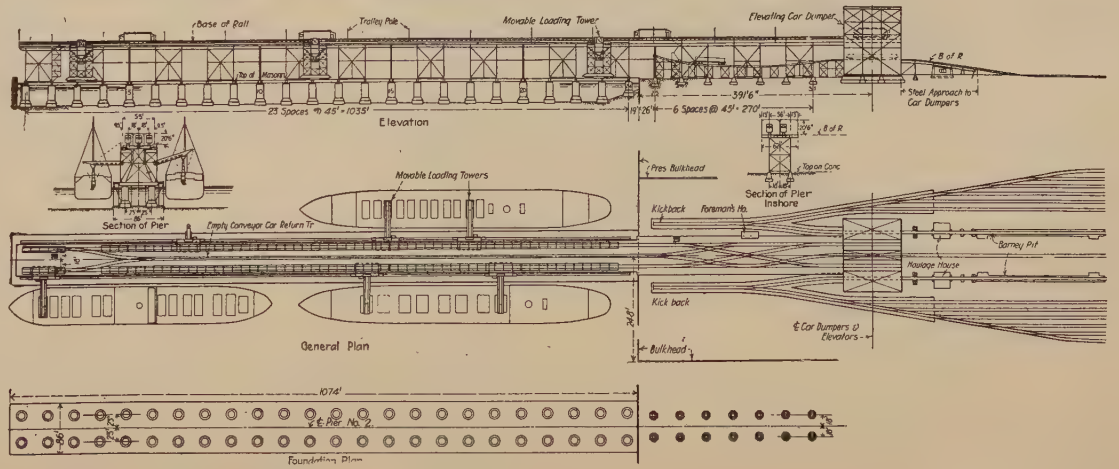


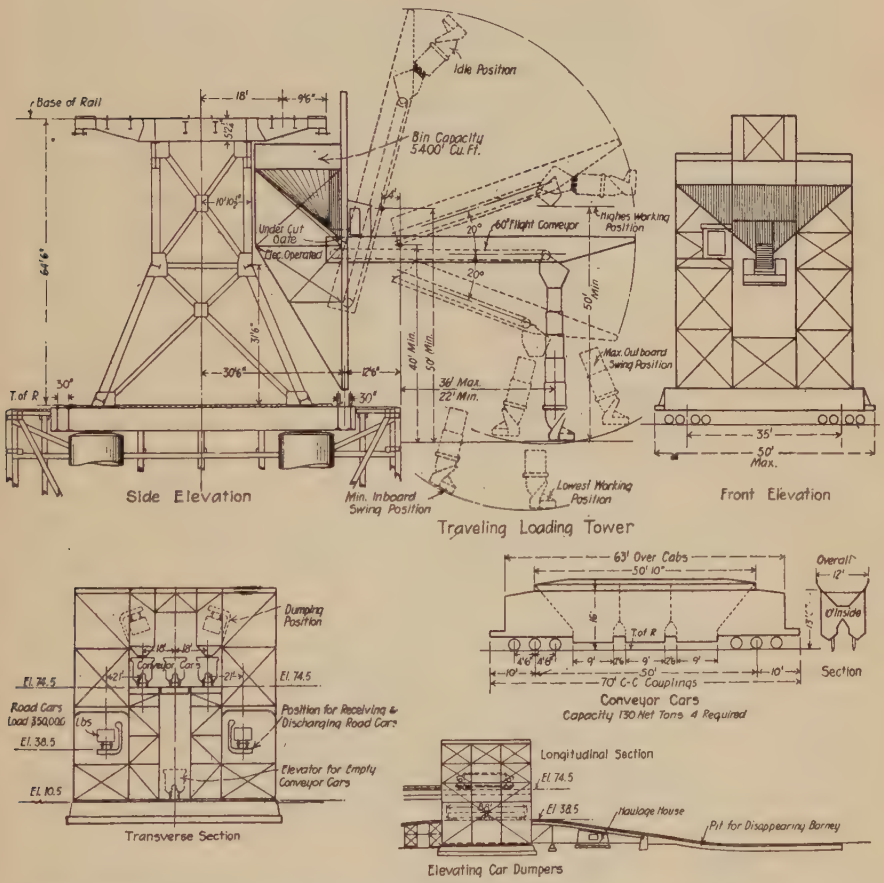
FIG. 220*A*.—Yard layout, and flood lighting, coal piers Nos. 1 and 2, Virginian Railway, Sewalls Point, Va.



(*Railway Review*, Mar. 15, 1924.)

FIG. 220*B*.—General plan and elevation of coal pier No. 2, Virginian Railway.

with mechanical trimmers, two on each side of pier, four 130-ton capacity conveyor cars, one railroad track scale for weighing coal cars up to 120 tons capacity, additional equipment and wiring in the substation, transmission wiring from substation to pier, yard tracks for loaded and empty coal cars, timber bulkheads, fender pier and kickback trestles, and dredged slips for docking and undocking of ships.



(From Railway Review.)

FIG. 221.—Elevation, sections, and machinery diagram, coal pier No. 2, Virginian Railway, Sewalls Point, Virginia.

The loaded coal cars will be pushed over the hump with a switch engine into the loaded receiving yard. They will then be dropped by gravity over the scales to a barney of the disappearing type which pushes either two small cars or one large car up on the cradle of the car dumper. The car dumper then dumps the coal into a steel container which is

elevated and discharges the coal into the 130-ton conveyor cars on top of the pier. The empty coal cars are then pushed off the cradle by loaded coal cars, the empty coal cars running by gravity to a kickback and thence to the empty car yard.

The essential difference is that in model No. 1 the shuttle car is elevated and lowered each round trip. In No. 2, the car dumper elevates the road car as part of the dumping process.

The loaded conveyor cars operate under their own power on top of the pier only and dump into the pockets of the traveling loading towers on either side of pier, after which they return on a middle track to the car dumpers for reloading with coal.

The coal from the pocket of the traveling loading tower is fed on a steel apron conveyor operating in the boom of the tower and is conveyed to a telescopic chute at the end of the boom through which it flows by gravity to a mechanical trimmer, and thence either by gravity over a curved surface of the trimmer or is distributed by a high-speed belt of the trimmer into the hold of the vessel. The substructure of the pier beyond the bulkhead will be constructed of concrete cylinders on untreated piles. The piles will be driven with a follower to, or cut off at, the proper elevation. The lower or 18-foot section of the cylinders will be filled with concrete under water. The water will then be pumped out, and after the laitance has been removed, the upper, or 12-foot section, will be filled with concrete in the dry. All concrete deposited in water and in the dry for foundation cylinders will be 1: 2: 4 mixture. The steel cylinder forms will be left in place for the protection of the concrete and piles.

The fender pier will be constructed of short-leaf, yellow pine timber and piling, creosoted in accordance with specifications of the American Railway Engineering Association. It will enclose and be entirely separate from the pier so that vessels coming in contact with the timber structure will not damage the foundations or steelwork. The fender piles will be constructed at the same time and by the same contractor as the substructure so the fender piles may be driven along with piles for concrete foundations, and the fender system used for bracing and supporting the steel cylinder forms until the concrete cylinders are completed.

The superstructure of the pier will be constructed of structural steel. The live loads will consist of the loaded and empty conveyor cars and the traveling loading and trimming towers.

Each car dumper and haulage will have a capacity of thirty dumps per hour.

The elevator will be operated by electricity at slow speed, as it will only be used occasionally.

A supporting and locking device will be furnished to hold the platform in its upper position.

Four electrically operated, self-clearing, conveyor cars, similar to those now in use on the present pier, will be furnished, each having a capacity of 130 tons of coal.

The body will be of heavy steel plate and reinforced to take the impact in receiving its load of coal from the steel container. It will be mounted on two six-wheel trucks and divided into three compartments for dumping into the pockets of the traveling loading towers.

Each loading tower will consist of a receiving hopper for transferring the coal from the conveyor cars on the top of the pier to a steel apron conveyor mounted in the boom. The apron conveyor will discharge the coal through a telescopic chute pivoted to the outer end of the boom, from which it passes either direct or through a mechanical trimmer into the vessel as desired.

The conveyor will be of the corrugated apron type, 60 inches wide, and built integral with the boom structure. The telescopic chutes will be circular in form and equipped with lifting and swinging mechanism. The boom will have a movement at right angles to the center line of the pier of about 14 feet, and the outer end can be raised or lowered for use in loading, or folded up out of the way when not in use.

The mechanical trimmer will consist of a steel structure with a rotating cowl and belt conveyor, suspended from the lower end of the telescopic chute. The trimmer belt will be 36 inches wide and travel at a speed of about 2,500 feet per minute. Coal falling through the telescopic chute will first pass over the cowl, which is circular in form in order to deflect the coal in the direction the belt is moving, and will then pass on the trimmer belt which distributes it at an average distance of about 35 feet in the hold of the vessel. When trimming is not required, the cowl is revolved through an angle of about 90 degrees and the coal then passes over the curved surface of the cowl and into the vessel.

The traveling towers operating with the mechanical trimmers will each have a maximum capacity of about 1,800 tons per hour and about 2,500 tons per hour when the trimmers are not in use.

The travel of the loading tower along the pier and the movements of the boom, telescopic chute, and trimmer will provide for loading all types of vessels at the pier.

The loading towers will be electrically operated throughout.

The track scale is for weighing the coal cars up to 120 tons capacity.

The dumping capacity will be 3,600 tons per hour for each car dumper, or 7,200 tons per hour for the pier.

The pier was designed by F. F. Harrington, Engineer of Structures of the Virginian Railway Company, and Chief Engineer of the Virginian Terminal Railway Company, a subsidiary of the Virginian Railway Company, with the assistance of J. E. Sharpley, Electrical Engineer, E. D. Hanes, Superintendent of Coal Terminals A. H. Chapman, Office

(*Courtesy of C. of E., U. S. A.*)

FIG. 222.—Coal tips at Cardiff, Wales.

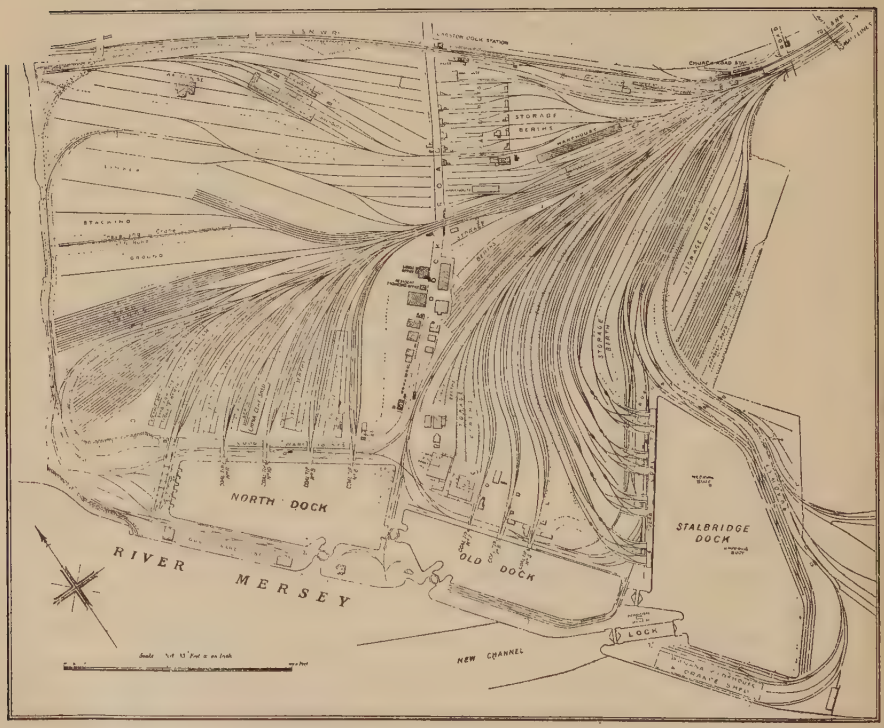


FIG. 223.—Yard layout for the European system of coal car dumpers. Garston Docks (Liverpool), London & N. W. Railway.

Engineer, and H. D. Hodgson, Assistant Engineer of the Virginian Railway Company, under the supervision and with the approval of H. Fernstrom, Chief Engineer of the Virginian Railway Company.

European Coal Tips.—In Europe at those ports handling large quantities of coal, mechanical car-dumping devices are installed in great numbers. These coal tips are quite different from American practice.

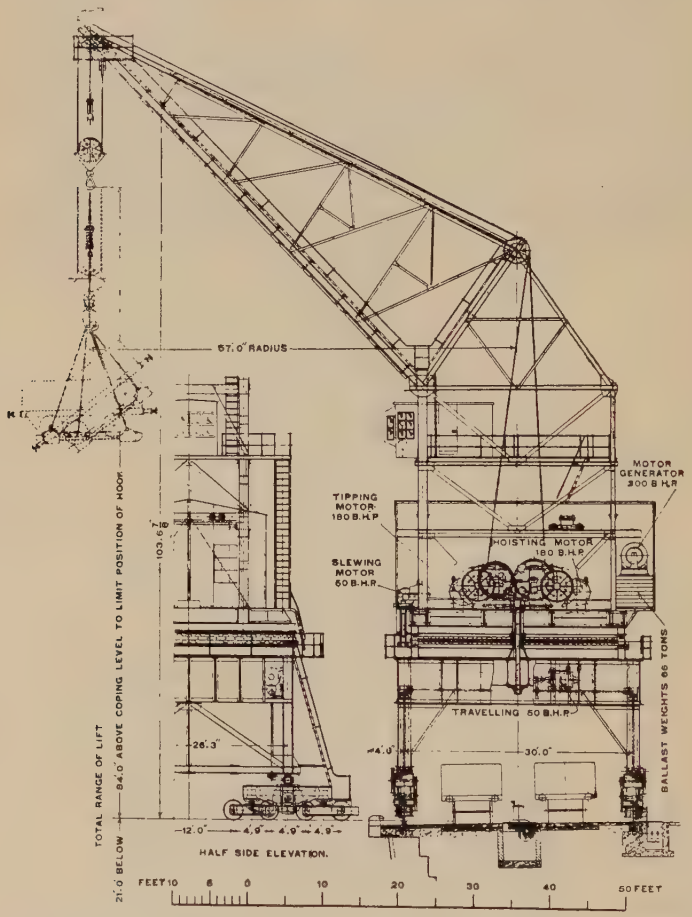
(Courtesy of Chief Engineer, Port of Rouen.)

FIG. 224.—A car dumping pontoon crane at Rouen (France). This type of car dumping machinery is common to British and Continental ports where 20-ton coal "wagons" are more readily handled than the American 50–100 ton types.

The differences start with the European coal car of 10-ton or 20-ton capacity on four wheels (two axles) and dumping through the end by dropping the tailboard as was the practice with the old two-wheeled horse cart. The emancipation from pre-railroad vehicle forms is as incomplete in the case of "goods wagons" as in side-door passenger wagons.

The small car and the tail dumping makes possible lighter and cheaper construction, with more units. It also causes the yards to be laid out at right angles to the quays (Figs. 222 and 223).

By multiplying units, the coal capacity of a port may be very great, but the speed of dispatch of any vessel loading coal at the port is much



(From article by Daniel Fife, M. E. Clyde Navigation Trust, Glasgow, in Dock and Harbour Authority, London, November, 1923.)

FIG. 225.—British method of coal car dumping, 35-ton electric coaling jib crane. General arrangement.

less, due to the slower operation in tons dumped per hatch. Vessel loading is also slower due to the fact that in most cases there is no bin storage at shipside in advance of berthing the ship, which, in the American system, makes it possible to feed the cargo coal into the ship at a high rate of speed. However, British practice varies according to the nature of the coal, which varies from very hard to very soft. The coal in Europe

is retrieved from stock piles in the yard and moved to the tipples for loading. Speed in American methods, however, is bought at the high price of the elaborate and expensive equipment.

Car-dumping Cranes.—One wide departure in European ports from American practice is the coal-wagon dumping crane, that picks up the coal car and lifts it over the hold where it is tipped and its contents dumped directly into the hold. Not much attention is given to the inevitably high percentage of degradation by this direct dumping method. But this equipment is not used at coal ports with a breakable quality of coal (Figs. 224 and 225).

The performance of these car-dumping cranes is of interest by comparison with American practice. An example as reported in the *Dock and Harbour Authority* is appended here, as a basis for comparisons.[1]

The leading particulars (Fig. 225) are as follows:

Maximum working load	35 tons
Test load for stability	60 tons
Radius (fixed)	57 feet
Total range of lift of block for general cargo	110 feet
Total range of lift of block for coaling	80 feet
Center of jib head above cope of quay	103 feet, 6 inches
Clear lift above cope of quay to bottom of cradle	65 feet
Lifting speed with load of 32 tons	50 feet per minute
Slueing speed with load of 32 tons	450 feet per minute
Traveling speed with load of 32 tons	60 feet per minute

The factors of safety are:

Structure and gearing	7 to 1
Hoisting and tipping ropes	8 to 1
Weight of crane complete with 66 tons of block ballast	315 tons

Coaling Cradle.—The cradle is of the "Armstrong" through type, capable of dealing with a wagon with 20 tons capacity of coal, and can be easily disconnected when the crane requires to deal with material other than coal.

The efficiency of one of the electric coaling cranes taken under test conditions is as follows:

EFFICIENCY TESTS

Weight in tons	Height in feet	Time in seconds	Power		Horsepower		Efficiency $= \frac{\text{L.H.P.}}{\text{E.H.P.}}$ per cent
			Volts	Amperes	Loads	Electricity	
32	50	40	490	365	162.9	239.74	67.5
24	50	37	495	280	132.0	185.8	71.0
17.15	50	35	500	220	99.8	147.4	67.7

[1] FIFE, DANIEL, M. E., Clyde Navigation Trust, Glasgow.

Several examples of the performance of this crane in loading coal into bunkers, the average lift being about 30 feet, are as follows:

PERFORMANCES

Steamer	Cargo tons	Hours	Tons per hour
Poplar Branch	1,489	6	248
City of Poona	5,290	31¼	169
King Edward	7,040	45½	155
Middlesex	3,510	21½	165
Clan McGilvray	2,112	11¼	188
Shahristan	1,544	8¾	177
Jason	2,050	11¼	181
City of London	2,973	17	175

Details of the working costs of shipping 464,255 tons of coal, almost exclusively into ships' bunkers, taken over the year 1922, are as follows:

WORKING COSTS

	PENCE
Wages of men on crane	0.23
Wages of cradle men	0.52
Electrical energy (88,985 units at 1.13 pence per unit)	0.22
Maintenance, inclusive of wire ropes and stores	0.26
Pence per ton	1.23

In comparison with Mr. Titcomb's best figures above, with car dumper and transfer car, namely 2.86 cents the British cost of 1.23 pence or 2.47 cents is a very good showing. More labor at a less wage and lower capital investment in England is cheaper per ton than labor saving at high wages through large capital investments in America.

The volume of coal handled through some European coal ports is very large.

The Rhine Harbor of Duisburg-Ruhrort is an example of a one-way port for shipping coal which comes from the mines in railroad cars. There are 8½ miles of basins, 96 miles of storage tracks besides stock piles to act as reservoirs. There are four coal shutes and twenty-nine car dumpers (much smaller cars than ours). Out of a total port movement in 1913 of 24,640,000 metric tons, 15,000,000 were from railroad to boat and only 2,600,000 tons from boat to railroad. The latter was chiefly ore from Rotterdam, for which there are two "fast plants."

UNLOADING, STORING, AND RECLAIMING OF COAL

As in the case of ore and, for that matter, with all bulk commodities loaded by gravity, the unloading of vessels requires a separate and distinct mechanical installation.

In the case of coal moved to the Head of the Lakes to be held in great reserve piles for distribution to the Northwest during the 5 months of large, male, adult winters characteristic of that part of the world, coal must be unloaded, stored, graded, and shipped out by rail or dray in huge quantities.

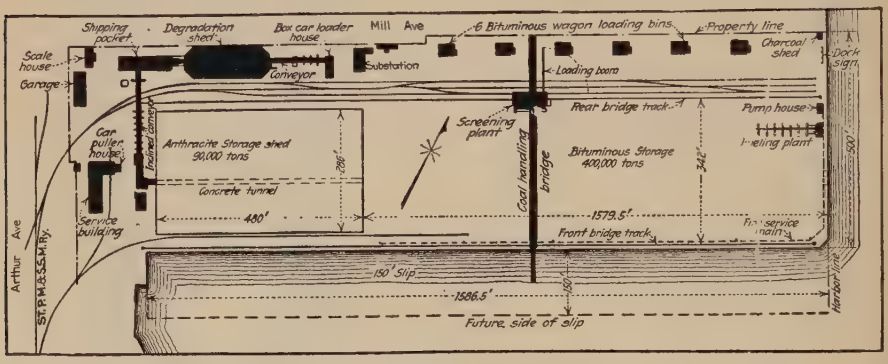
The standard practice of unloading is by bridge cranes and traveling buckets (Figs. 226, 227, 228, and 229). The unloading is so closely connected with the storing that it is one operation. The traveling bridge crane moves along the wharf spanning a wide stock-pile area. The hinged boom at the wharf end when lowered extends out over the vessel. The cantilever extension at the land end reaches grading, screening, and car-loading mechanisms. The layout of a typical coal yard and the further distribution of the coal are seen clearly from the diagrams (Figs. 228 and 229). This is a typical layout (Dock No. 4, Northwestern Fuel Company, Rices Point, Duluth, Minnesota). It covers a filled area 500 by 1,765 feet with a vessel slip 150 by 1,565 feet. The wharf has a storage capacity of 400,000 tons of bituminous coal and 90,000 tons of anthracite. Each kind of coal must be handled separately and each has elaborate equipment for screening, grading, conveying, storing, and loading into the different sizes into box or gondola cars.

The capacity of each bridge is about 625 tons the hour, when working in fine coal (not caked nor frozen). The span of the bridge between supports is 342 feet with a total overall length of 571½ feet. The operating speeds are hoisting 200 feet per minute, trolley travel 1,000 feet per minute. Bridge speed laterally along the wharf is 50 feet. The bucket is of the

FIG. 226.—Bridge crane type coal unloading rig, Duluth.
(Photograph by the author.)

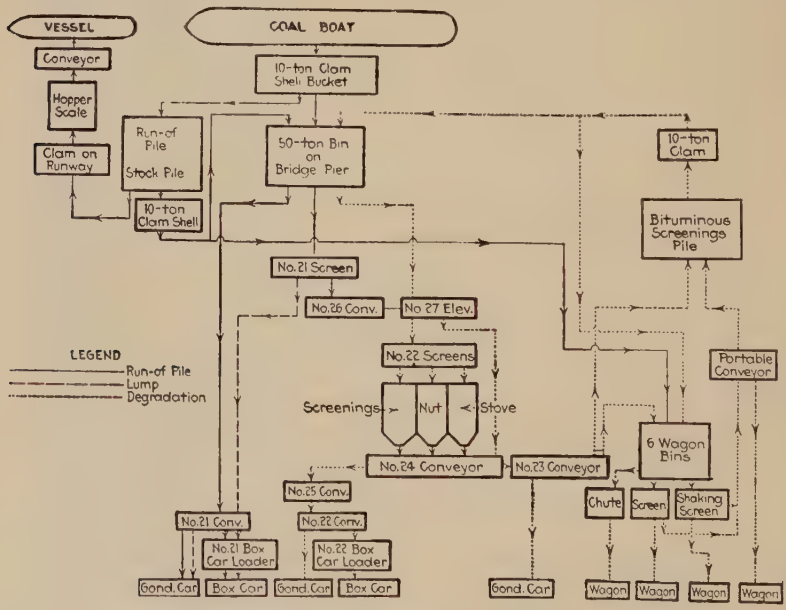
clamshell type, 6-ton capacity, 6½ feet wide, and 22 feet spread; clearance above wharf 50 feet.

Storage of Coal.—In all coal operations there is the question of storage. The outstanding problem along with piling and retrieving is



(*From Engineering News-Record, Jan.* 19, 1922.)

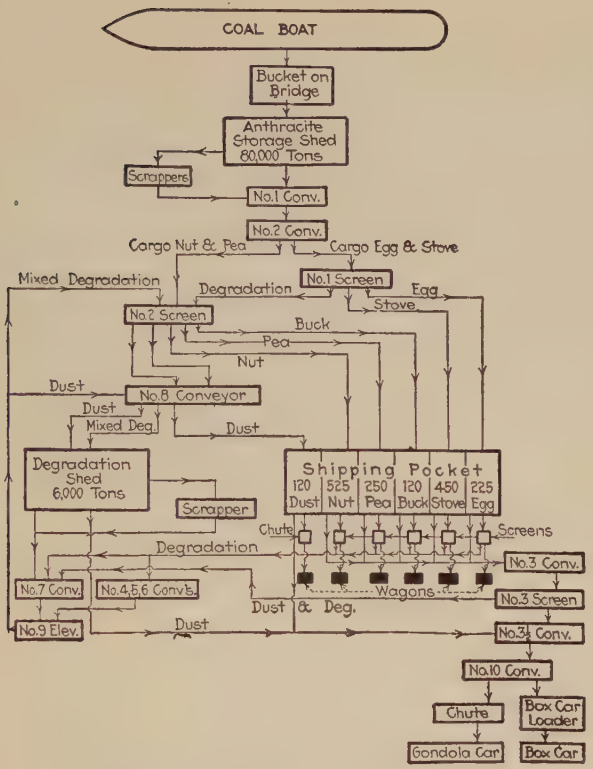
Fig. 227.—Dock for unloading, storing, screening, and shipping coal, Duluth, Minn.



(*From Engineering News-Record, Jan.* 19, 1922.)

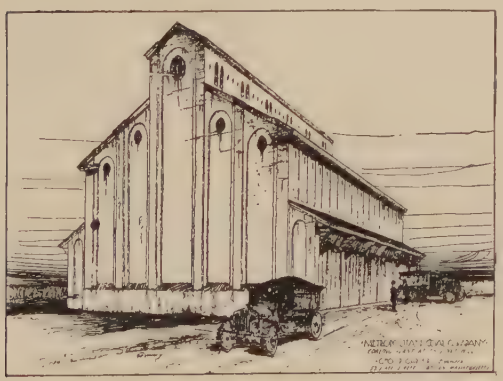
Fig. 228.—Flow diagram of bituminous coal.

the danger of spontaneous combustion. Bituminous coal does not suffer very greatly from oxidation of the air and the danger is not from deterioration through slow oxidation to a degree that makes storage under water necessary. Coal piles sometimes ignite and burn inside for months.



(From Engineering News-Record, Jan. 19, 1922.)

FIG. 229.—Flow diagram of anthracite coal.



(From Coal Trade Journal, Apr. 30, 1917.)

FIG. 230.—Architecturally artistic coal bin built at Boston in a residential district with noiseless and dustless operation combined with the effect of a Romanesque Basilica.

Freshly broken surfaces oxidize most rapidly and this creates sufficient heat to ignite the pile. Therefore, coal must be handled to avoid breaking. Ventilation will keep down the temperature. But coal dropped onto conical heaps will have a tendency to break, showing a fresh surface. The large pieces will roll to the bottom where there is much air space for oxidation, while the fine coal will cover the top of the pile preventing ventilation that should keep down the temperature. Careful heaping in rows, with as little breakage as possible, should reduce the risk of combustion.

The other method from storage in the open is storage in concrete bins where the air is shut off almost entirely, thus reducing oxidation, heating, and fire.

Sightly Coal Bins.—Coal distribution plants are uniformly noisy, dirty, and ugly. This need not be so. Where smaller storage and distribution plants are necessary in the neighborhood of parks, residences, or city planning and beautifying programs either on the waterfront or inland, a little study will make a coal bin a thing of beauty, strange as this may seem. In Fig. 230 is shown a concrete coal bin cast in the form of a Romanesque basilica. All machinery and dust-producing features are enclosed and in themselves designed to reduce noise to a minimum.

BUNKERING COAL

Ship Bunkering.—The discussion of coal and bulk freight handling would not be complete without brief mention of the very important process of ship bunkering. It is assumed that in a well-regulated port the coal harbor is a roomy and well-equipped institution. Such a coal harbor will always have the economic advantage because in concentrating all the available coal traffic at one point it is possible to install the best available equipment and yet have the per ton expense of loading, and unloading, reduced to a minimum. The coal harbor of a port would have fast plants for unloading, the most improved loading machinery, and the necessary upland for car storage and classification yards.

But make this coal harbor as complete as it can be, and even then ships will not bunker there. Ships will go to the coal harbor to get cargo coal but not bunker coal. A coal ship would bunker there not because it is a coal harbor, but because the coal harbor would happen to be the ship's berth while in port loading or discharging cargo coal. Usually bunker coal will be brought to the ship and not the ship to the coal pockets. A ship in port has no time to shift its berth unless it be from a discharging to a loading berth. Therefore the coal lighter, with bunkering machinery if possible, but always the coal lighter, will come to the ship.

(*Service Photographique Gouvernement Générale de l'Algérie.*)

FIG. 231.—The Port of Algiers, French North Africa, has modern coal handling equipment as a bunkering port.

FIG. 232.—At the Port of Rouen, France, shore gantry cranes handle the coal with clamshell buckets. This is a type of mechanical installation where the movement may not be permanent as the cranes may be shipped or moved along the quay and the clamshell changed to another equipment for general cargo.

In the Caribbean at Bridgetown and elsewhere, ships are coaled by native women who carry small trays of coal on their heads. In many ports the coal is brought alongside in lighters and shoveled into buckets which are raised by the ship's tackle and dumped into the chute to the bunkers. The bucket and shovel system is slow and wearisome. Even if it be possible to bunker a ship by this means during the time she is discharging and loading, it is expensive except in such ports as have a

(*Photograph by the author.*)

FIG. 233.—A Catamaran steam bunkering equipment at Bergen, Norway. Traveling grab-bucket discharge into hopper feeding ship's bunkers.

very low daily wage as in the Far East or West Indies. As ships grow larger and faster, consume more coal and yet stay a shorter time in port, something must be done to speed up bunkering. There have been many ingenious developments.

At Bergen, Norway, the writer watched an excellent floating bunker machine. It consisted of a tower carrying a bridge crane of the tramway and grab-bucket type, as in a fast plant. The track, which was quite high to accommodate large ships, consisted of the bridge span and the two projecting booms. The interesting feature was the foundation of

the legs of the bridge on two separate floats, catamaran style. These spread legs enabled the coal lighters to set either between the legs or outside the outer leg. By having two berths for the lighters, no time was ever lost in shifting an empty for a loaded lighter. The clamshell bucket was of the familiar type and it discharged into a hopper which fed the coal into the bunkers. One man in the tower operated the entire machine except for shifting the barges and a little trimming. This seemed to be a truly efficient bunkering system (Fig. 233).

(*Photograph by Irving Underhill.*)

FIG. 234.—Bunkering the *George Washington* by the Mischner System.

Recent developments of the continuous-motion principle in bunkering are the De Mayo and also the Mischner portable elevators. The machines consist of a bucket belt in a casing containing the motor which drives the belt within the casing, thus making the machine self-contained. The lower end allows the buckets to bite into the load of coal. The entire machine is suspended from a boom and allowed to sink into the coal by its own weight. The coal is elevated by the buckets on the

chain and discharges into a flexible spout which feeds it into the ship's bunkers.

The capacity may be increased by increasing the number of the units. This gives great flexibility in the use of a bunkering equipment. A ship

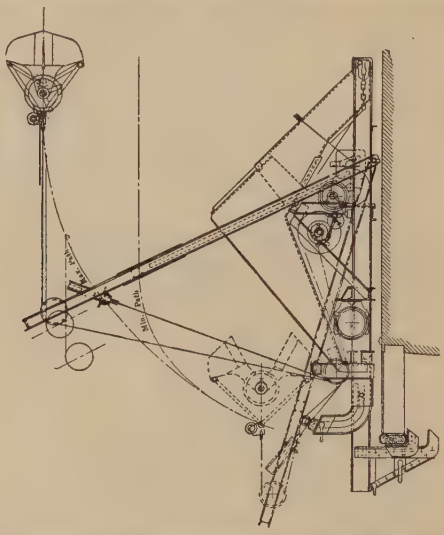
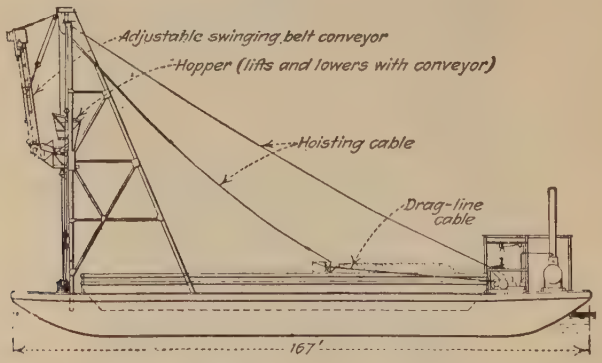


FIG. 235.—Details of a suspended bucket system of coaling equipment, showing method of operation.



(*From Engineering News-Record, Oct.* 13, 1921.)

FIG. 236.—Ship coaling unit embodies dragline and conveyor. Capacity 1,000 tons.

bunkering at the pier is eased off from the piers with booms far enough to allow coal barges to come along the pier side as well as the ship side. The De Mayo Company states that frequently they have put 8,500 tons of coal into a large vessel in 21 hours, using ten machines. On one occasion the firm bunkered the *Imperator* (1914) with 8,200 tons of coal in 19 hours (Fig. 234).

These companies are in the bunkering business and have developed their own equipment for their own use.

The large number of vessels changed over to oil burners and the many new motor vessels are making inroads on the coal bunkering business.

Suspended Bucket Rig.—A self-contained clamshell bucket rig for coal bunkering has taken its place with the two self-contained, belt-conveyor units just mentioned. The digging principle is different, but in common with them this equipment is hung onto the side of the ship by a derrick and as many can be operated at a time as the ship has bunker openings. The clamshell principle of digging is applied in miniature to this interesting bunkering rig (Fig. 235).

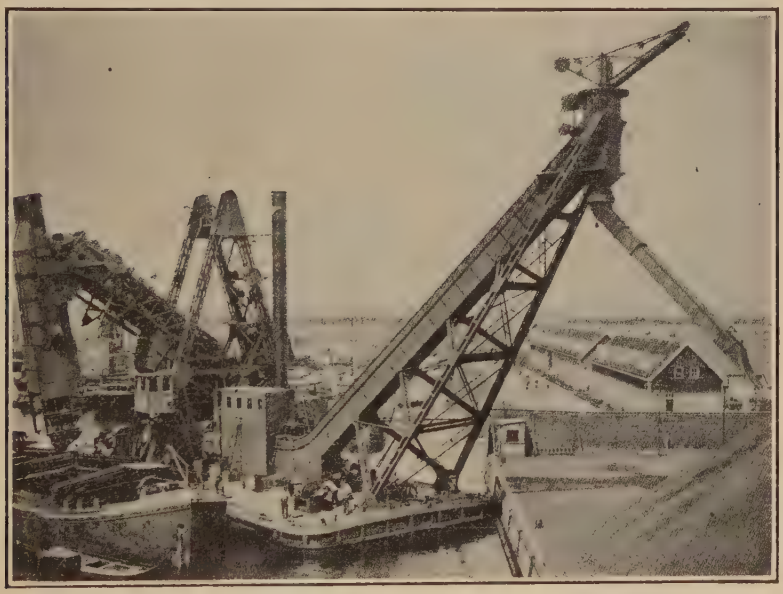


FIG. 237.—Floating coal elevator-transporter at Amsterdam.

A Barge and Dragline Bucket system of bunkering has been operated at Galveston. A *V*-shaped hopper scow carries self-propelling and operating power plant and dragline rig, a simple coal-handling unit of 1,000 tons capacity. This barge carries the entire equipment for transferring coal to fuel bunkers of steamers without the necessity for shipboard equipment. It was designed primarily for flexibility of operation. It is operated by two men, an engine runner and a fireman.

An outline side elevation of the barge is shown in Fig. 236.[1] Coal is handled from the self-trimming barge by a scoop bucket of 1½ tons capacity. However, only one bunker chute can be served at once when a dozen are available on large vessels.

[1] The barge is operated by the Galveston Coal Company under the supervision of Wesley Merritt of that firm. It was designed and built under the Evans and other patents by the Lidgerwood Manufacturing Company, New York City, owners or licensees of such patents.

Elaborate Bunkering Rigs in Europe.—Some ports have very elaborate and expensive equipment for bunkering vessels. An example of such a rig is the floating coal handling plant at Rotterdam, Fig. 237. The bunkering rig consists of a barge carrying a huge chain and bucket digging unit mounted on a steel tower and capable of being revolved or inclined as occasion demands. The capacity per bunker opening served must be very high, but the difficulty always is in the trimming of

Fig. 238.—At Havre and other French ports floating steam cranes with gooseneck jibs are used interchangeably for bunkering, with hooks, with clamshells, or for general cargo, as here. The floating equipment is more mobile and permits greater concentration where required: also, less idle time of the cranes compared with wharf equipment.

the coal in the bunkers which sets the limit of the capacity at any one bunker compartment. It seems to the writer that better policy is smaller and less expensive units and more of them.

Gooseneck floating revolving cranes, Fig. 238. In the final analysis the most useful piece of harbor equipment is the small handy floating crane of the whirler or revolving type with a gooseneck boom, a boom with a slight bend near the peak. This type can work a clamshell bucket for bunkering or by replacing the bucket with a hook, handle general cargo from lighters. So popular is this type at Havre that most of the hoisting machinery of the port is now of that type. There are over 400 of them. They are even used in the place of wharf cranes by bresting the ship off and lying between ship and wharf.

CHAPTER XVI

BULK FREIGHT—LIQUIDS AND GRAIN

HANDLING AND STORAGE OF OILS AND OTHER LIQUIDS

Oil handling is a field in itself. It will only be possible here to indicate the general nature of such terminal facilities and to place them on the list of the necessary equipment at any modern port.

There are three or four important groups of oils or liquids handled like oils in bulk by pumps, pipe lines, and tanks.

1. Petroleum and its products from crudes to gasoline and lubricating oil.
2. Vegetable oils such as soya bean oil, cocoanut oil, etc.
3. Latex (milk of rubber), turpentine, molasses, etc.
4. Some acids.

These products are pumped into and out of bilge, peak, bunker, or cargo tanks or tank ships and into storage tanks or tank cars.

In addition to pumping and storage machinery, many heavy liquids such as tarvia or molasses require heating coils at low temperatures to make pumping possible.

Petroleum is pumped in all its movements. It requires careful handling because of the great fire hazard. The danger to shipping in the port from floating oil fires on the surface of the harbor waters has led to the construction of petroleum basins in many ports, to localize the risk. Petroleum movements are for two or three principal ends: first, crude petroleum moved in tankships to refineries; second, petroleum products moved to distributing centers for inland traffic; and third, bunkering stations throughout the world for oil-burning vessels.

All of these are important and have received much discussion in recent years due to the threatened gasoline shortage for motor cars ashore and the threatened petroleum shortage for merchant and naval vessels. The yearly additions to the world's fleet of motor ships will undoubtedly proceed with acceleration. The diesel engine ship is gradually making the old type of burning of oil under boilers to make steam—an economic atrocity—a thing of the past. This is already true of smaller and medium-sized cargo and passenger services. According to the United States Trade Commissioner at Copenhagen, Harry Sorensen, the Danish motor fleet alone increased from 875,000 tons in 1914, to 1,040,000 tons in 1921. The internal combustion, oil-burning engine

will reduce greatly the consumption of petroleum per ship or per horsepower, but there will be so many more ships using petroleum fuel that the total consumption will increase. Consider the provision at the key ports of the world for oil bunkering of all these vessels and the great movement of bulk crude oil or petroleum products from wells to refineries and distributing centers, and the magnitude of the question of adequate oil storage and pumping machinery to give quick dispatch to tankers and safety to harbor shipping is obvious.

The elements for consideration of the petroleum movement at ports are; (1) a petroleum harbor separated by guard locks from the rest of the harbor to accommodate all forms of craft; (2) floating equipment, lighters or barges for bunkering ships in the harbor; (3) canal or river barges for distribution by inland waterways to the interior, such as the Elbe and Rhine River barges serving the ports along these waterways; (4) tank cars on the railroads and proper provision for the same in the harbor layout; (5) storage tanks in the harbor; (6) provision for adequate disposal of sludge from fuel tanks to prevent it being discharged into harbor waters. Fuel tanks should be flushed out, and the discharge should be into a sludge barge to remove the sludge to some point where it might be utilized commercially. At least, it should be pumped into some enclosed area from which the water may seep through sand and the petroleum residue be separated out to prevent its floating on the harbor waters; not only because of the danger of fire, but because the appearance of yachts and passenger vessels is greatly injured by the thick cake of oil accumulated above the water line on the otherwise immaculate sides of these vessels. Also, oil refuse kills fish and shellfish for considerable distances. Furthermore, oil refuse on beaches and waterfront structures accumulates, soaks into wooden structures, and makes the entire waterfront one big fire hazard.

Oil Pollution and Bunkering.—The operation of oil bunkering at the berth and the removal of sludge to prevent pollution of harbor waters have been combined in the development of modern sludge and fuelling barges. The problem of fuelling while a ship is at her berth rather than shifting the vessel to the petroleum harbor is based on the same principles as that of coal bunkering. The fuelling barge is rather a simple mechanism consisting of tanks (usually 2,500 barrels or more) with pumps and long hose connections.

Sludge removal from tanks and oil salvage is more difficult because of the heavy nature of the material to be pumped, the height it must be lifted, and the difficulty of separating the oil from the water with which it becomes mulsified. But all modern port authorities prohibit dumping of sludge or other oils into harbor waters and demand that fuel tank sludges be removed in some other way. Oil fuelling barges are now constructed to sludge out the fuel tanks and to bunker them.

One example of such sludging equipment may be given,[1] the Wheeler System, New York. There is also the Todd System, and the Standard Oil Company has worked out its own methods of, and equipment for, sludging and bunkering. There are doubtless many other systems.

An Oil Sludge Removal Barge.—In the oil tank and attached to a flexible hose is a nozzle. The nozzle is globular in shape, having air inlet holes spaced circumferentially around it. A tubular extension of several inches projects beneath it (Fig. 239).

It will be noted that there are two tanks on the deck of the barge with an air pump placed between them. These tanks discharge to the hold of the barge, to tanks ashore, or to a tender alongside. The intake of the nozzle is immersed in the sludge to be removed, but not deep enough to submerge the air inlet holes in the globular body. Using a working vacuum of only 20 inches, air is drawn through the inlets with a velocity of approximately 800 feet per second, and in so doing, mechanically breaks up oily residue until it is minutely subdivided and suspended with the drops of sludge water in the moving air stream inside the hose. The sludge, which is as heavy or heavier than water, is emulsified and drawn up through the flexible hose and into one of the cylindrical tanks shown. When one of the tanks is filled, the suction is by-passed to the other tank, while the discharge from the full tank to the hold of the barge is opened and the emulsified oil blown into it. The contents of the tanks can also be discharged by means of compressed air to receptacles on shore or to a tender alongside. After this emulsified product has settled in the hold of the barge the oil will rise to the surface of the water. The bottom settling water is discharged overboard and the oil residue, which is now free of water, is suitable for burning under the boilers.

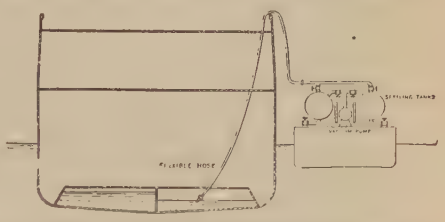


FIG. 239.—Section through salvaging barge and vessel from which sludge is being removed.

A very important claim for this system is that the obnoxious and dangerous gases that are generated in oil tanks are pumped out with the air and sludge. The settling ordinarily is effected in 3 hours. A striking example of the low specific gravity of the emulsified residue was shown on a recent job on the *American Legion*. One of the barges pumped 150 tons of oil residue from the forepeak of the *American Legion* in 44 hours against a head of 65 feet.

The text of the British Regulations against the discharge of oil into navigable waters is given in Appendix I.

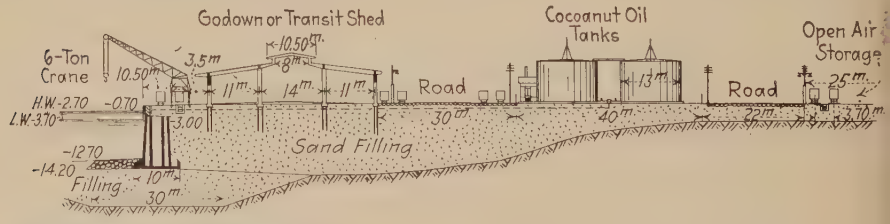
[1] ENGSTRAND, GUNNAR C., M.E., B.A., Chief Engineer, Donnelly Dry Dock Company, Inc., New York.

Vegetable Oil in Bulk.—The growth of world traffic in vegetable oils during the last decade has been phenomenal. There is soya bean oil from Manchuria, China, and Korea. There is cocoanut oil from the tropics, although the greater part of the movement of this commodity is still in

(*Courtesy of Port Director A. G. King.*)

FIG. 240.—The *Altai Maru* of Osaka discharging soya bean oil into tank cars on apron tracks of the Municipal Terminal (Army Supply Base) Norfolk, Va.

the form of the copra to be pressed in northern crushers. There is an increased movement of linseed oil in bulk, also of cottonseed oil. In principle, the movement of these oils is not dissimilar to the movement of crude petroleum and petroleum products. In detail, the equipment



(*From Dock and Harbour Authority.*)

FIG. 241.—Cocoanut oil tanks, Juliana Quay, Macassar, D. E. I. Pipes lead to the wharf with flexible hose connections.

is smaller and considerably finer, to avoid leakage and loss of commodities of much greater value. Tanks are smaller because of the necessity for holding together many various grades or qualities of the product. Pacific ports have given a great deal of attention to the movement of vegetable oils from the Far East (Figs. 240, 241).

Mr. Rossbottom,[1] some years ago, found that by sludging out the fuel tanks of the oil-burning vessels emptied on the outward run to the Orient, it was possible to utilize this space to carry oil back to the States. Freight money for vegetable oil carried in bulk in the fuel tanks is velvet on the voyage account.

Where oil is shipped in containers, it has been found profitable to remove the oil from the containers in order to store and ship in bulk.

Molasses.—Similar to the movement of vegetable oil in bulk is the growing movement of black strap molasses from Cuba. This is the residue after the sugar is crystallized out and is used in cattle feed, in certain kinds of boll weevil insecticides, and for other purposes. The equipment for handling vegetable oils is usually satisfactory for handling molasses in bulk except in cool weather.

Liquid Latex.—Another bulk liquid cargo is coming into prominence in the Far Eastern trade, that of liquid latex or milk of rubber. There are new successful processes being developed in the rubber industry that use raw cotton and the sap of the rubber tree eventually to turn out an automobile tire. Also more economical and efficient methods of treating the sap to produce pure rubber for various formulae and processes have been, and are being, discovered. Ships in the Far Eastern trade have had their peak and bilge tanks fitted with hose openings to accommodate this latest liquid bulk commodity. There is no essential difference in port equipment between handling latex and bean oil, although each traffic will doubtless develop its own refinements.

Ballast.—Unfortunately, for the ship operator, many legs of a voyage must be made in ballast. Water ballast is insufficient in itself except in tankers in which the compartments are flooded. It is therefore necessary to load sand or gravel and discharge this again at a distant port. Loading is similar to coal loading. Cars of gravel may be dumped over a tipple. To get it out again is more work. A device similar to that used in bunkering a ship, consisting of a 65-foot boom attached to a barge with an electrically operated, 30-inch bucket elevator, has been developed to remove sand or gravel ballast. This barge will discharge sand or gravel into the hold of the ship by means of this boom rapidly and cheaply, or take it out again. Discharge of ballast at an unequipped port is usually made by attaching small grab buckets to the ordinary ship's gear.

Dumping of ballast into harbor waters is prohibited in all commercial ports. The same rules apply to ashes and cinders, which must be removed by lighters. Stevedores, towboatmen, chandlers, bunkering firms, and operators of similar waterfront activities engage in the business of removing ballast and ashes. They also supply fresh water. Most of a ship's ashes are dumped at sea.

[1] Vice-president of W. R. Grace and Company.

GRAIN SHIPPING AND STORAGE

Grain is another specialized commodity that requires special equipment throughout. On the railroads it is usually shipped in box cars. It requires three different sets of machinery: (1) for loading, free flowing by gravity; (2) for unloading, it is pumped by chain-bucket conveyors or by pneumatic elevators using suction; (3) horizontal movements are usually by rapid traveling belts, sometimes by revolving screw. These various methods of moving grain are combined in the warehouse, which is the grain elevator, in the marine legs for unloading in grain galleries with spouts for loading, and in the connecting conveyor galleries for lateral movements.

Grain is a very important and desirable ship's cargo and constitutes one of the fundamental or basic cargoes in world shipping. Not only are great quantities of grain moved about the world from points of surplus production to points of inadequate production in order to feed the world's millions, but in quality, grain is a desirable cargo because it stows approximately at par weight and measure. It is clean, and it can be readily handled at all ports having the necessary special machinery. A port without an export grain elevator will not get any grain for export.

Ships Load Full Cargoes on Charter at Many Important Grain Ports. Grain is an extremely desirable cargo to fill out a load for liners that must sail on time and hold their schedules regardless of cargo bookings for that voyage. For this reason, grain is on the free list for steamships' conference tariffs, and the liner operators are at liberty to quote any tariff they wish in order to get the business to fill out a short load, that is, distress room, a few hours before sailing. For this reason, at important ports like New York, and even at great specialized grain ports like Montreal, the liners carry a large proportion of the grain exports. On the other hand, at South Russian and Rumanian ports, or at many Argentine ports, full cargoes of grain in chartered vessels still prevail. We find a similarity with the case of coal in that ships carrying full cargoes can go to the grain elevator, but at New York the grain is lightered from railroad elevators to shipside by floating equipment, the grain being put into the ship by this special machinery, as was the case in bunkering. A third type of facility, however, has been developed to handle both grain and general cargo at the same wharf by shore machinery through the use of long conveyor galleries above the transit shed. This system of loading grain and general cargo simultaneously, or taking part cargo of grain in one or two holds, has its examples at such ports as Montreal, Quebec, Boston, Portland, Oregon, and Sydney, Australia, where the grain gallery is usually a part of every wharf equipment (Figs. 242 and 243).

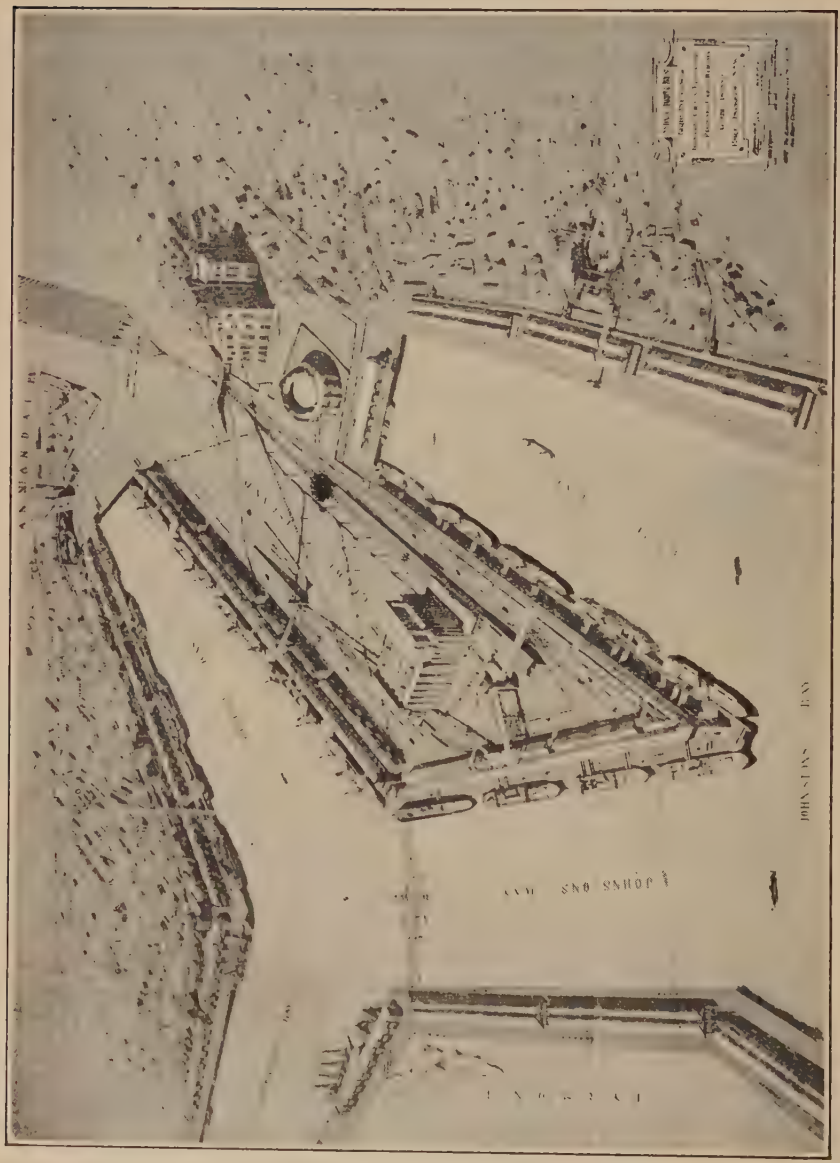
Grain Cheaper to Handle than Flour.—The millers of the United States have frequently made protest to the United States Shipping Board that the rates on bulk grain were so much lower than on the milled products—flour, bran, feed, etc.—as to be in the nature of discrimination. This difference in rates has a very decided justification in the difference in the costs of stevedoring the two cargoes and does not constitute an arbitrary discrimination against flour in bags as against grain in bulk. The stevedoring rate for bagged wheat and flour on the Pacific coast, according to the *Marine Review* of Sept. 27, 1922, was 45 cents a ton. At some Pacific ports it is the custom of the steamer to take delivery of cargo within 200 feet of ship side, which sometimes causes considerable extra expense. For bulk grain, the stevedoring charge is ½ cent a bushel, or ¾ cent if there is less than 6 feet headroom. This gives a rate of 22 to 24 cents a ton. To this must be added the bagging charge for grain

(*Photograph by the author.*)

FIG. 242.—Quebec, Canada, modern combination general cargo and grain-loading facilities.

used in topping off the cargo. This, however, does not exceed a few hundred dollars, including the bags, in most grain steamers. The difference to the steamship operator in favor of bulk grain is about 15 cents a ton on the stevedoring; also, bulk grain can be loaded much faster than bagged grain or flour. Under proper conditions, a ship can load bulk grain in 5 working days, as against 10 or 12 required for package freight, including flour in bags. Therefore, the saving in stevedoring costs and in ship's time is very considerable.

There is another cost against the bulk grain in favor of sacked cargo that occurs when the ship does not carry a ceiling or lining for the holds of a permanent construction for grain in bulk. The estimated average cost of lining for bulk is 50 cents a ton as against 30 cents for cargo in sacks. The lining of a standard 9,400-ton deadweight steamer costs about $3,000, taking the cost of lumber at the time of these calculations, as against approximately $5,000 for grain in bulk. Also, there are the costs of fitting shifting boards amounting to 18 to 20 cents a ton of cargo in Puget Sound, or 27 to 30 cents a ton at Vancouver. Even with these

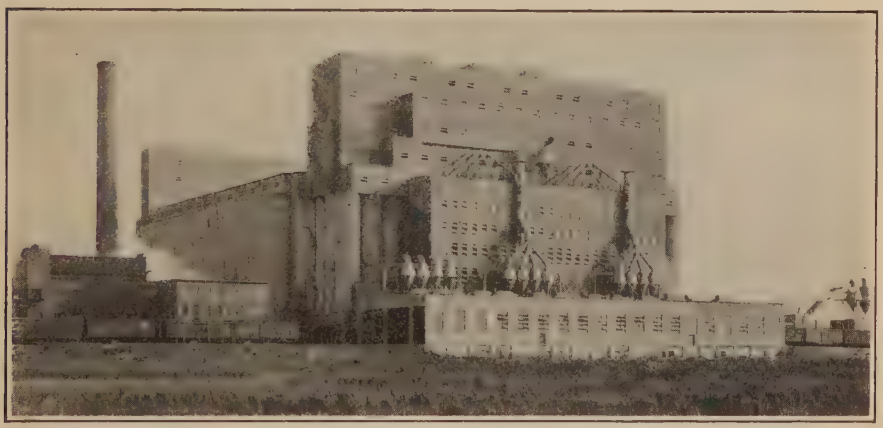


(*Courtesy of Sydney Harbour Trust.*)

FIG. 243.—Terminal grain elevator in combination with cargo berths, Glebe Island, Port Jackson, New South Wales. Quay type of development.

calculations, a ship not fitted with permanently grain-tight ceiling would still have a little less of a margin, but on the average of all ships suitable for the grain trade, bulk grain can be handled for about half the cos of mill products in bags.

Grain Loading. Grain Stowing.—Under the old practice on the Pacific coast, the Board of Underwriters insisted that a steamer loading sacked grain or flour be lined throughout and that shifting boards be fitted in between decks and to 4 feet below between deck beams. The underwriters made these rulings in the old days when sailing vessels carrying grain cargoes went around the Horn, a very long and a very stormy voyage, and remained in tropical waters for many days, so that



(Courtesy of John S. Metcalf Company, Chicago.)

FIG. 244.—A 10,000,000-bushel grain elevator of the Chicago and Northwestern Railroad at Chicago, said to be the largest grain elevator.

careful lining was necessary to protect the cargo. The lining and the shifting boards were necessary for the protection of the vessel in order to keep the grain from shifting in heavy seas, from consolidating on a long voyage, and from sifting into the bilges. These conditions are changed and more liberal underwriting rules have been, and are still being, inaugurated. Recent regulations for loading grain similar to those of Montreal are now applied to Vancouver and require that the ceiling over the water ballast tanks be made tight by calking or nailing 1½ by 2-inch battens over the seams. Shifting boards must extend from the keelson to the upper deck. Feeders must be provided according to the construction of the ship to take up the space made through the gradual consolidation of the grain under way or the grain must be secured by topping over with six tiers of bagged grain on a platform.[1]

[1] See also "Wharf Management, Stevedoring and Storage," MACELWEE and TAYLOR, D. Appleton & Company, 1921.

The practice prevails to ship grain in bulk wherever possible because of the ease of handling bulk grain with modern machinery.

The Grain Elevator.—The hub of all modern grain operations is the grain elevator. At all points along the journey we find the elevator. First, there is the local elevator at the shipping points in the farming district, then we find at great grain markets such as Port Arthur and Fort William, Canada, Duluth, Superior, Minnesota, and Chicago, great elevators that take the grain from the rails in a clean, dry condition. It is next stored, and then loaded into a vessel or cars for further transportation. At Buffalo we find another great transfer point from Lake vessels to canal barge or railway cars while at Montreal, transfer is made to ocean

(*Photograph by Harvey.*)

FIG. 245.—Public grain elevator and wharf, also public cotton warehouses and wharf, New Orleans.

ships. At seaboard, as far south as Norfolk on the Atlantic, and especially at New Orleans in the Gulf and at various points on the North Pacific coast, we find tidewater elevators of large capacity. Elevators have grown in size and in efficiency. The world's record in capacity is claimed by the Chicago and Northwestern Railroad elevator in Chicago with a capacity of 10,000,000 bushels (Fig. 244). Probably the greatest elevator at tidewater is the central elevator at Montreal with 4,000,000-bushel capacity. Many other very large elevators are found along the routes of the golden stream of the world's bread supply.

One of the recent developments in elevator equipment that has been a great factor in the growth of the port, has been the great municipal elevator at New Orleans. The first portion was built in 1916 with about 1,000,000 bushels capacity, but this has since been increased to 2,600,000 (Fig. 245).

GRAIN RECEIVED AND DELIVERED FROM THE NEW ORLEANS PUBLIC GRAIN ELEVATOR SINCE THE BEGINNING TO THE END OF AUG. 31, 1924

Year	Receipts, bushels	Deliveries, bushels	Stock on hand, bushels
1917	7,937,814	6,861,307	1,076,507
1918	21,744,840	21,397,559	1,423,788
1919	14,676,991	13,555,387	2,545,392
1920	17,826,760	18,835,294	1,536,858
1921	41,940,700	42,279,021	1,198,537
1922	28,952,822	28,251,094	1,900,265
1923	26,205,234	27,505,191	600,308
1924	13,173,438	11,352,008	2,421,738
Total	172,458,599	170,036,861	2,421,738

Number of bushels shipped through the port during the year ending Aug. 31, 1924 12,193,235

Modern Construction Methods.—The construction of the monolithic concrete grain elevators has reached a high state of development, as well as the mechanical installations. A splendid example, as typical of this phase of engineering, is to be found in the construction of the New York State Barge Canal grain elevator on Gowanus Canal, New York.[1]

In the construction of this grain elevator, the contractor poured the storage bins, which are 94 feet 8 inches high and cover a ground area 408 feet in length and 69 feet 4 inches in width, out to out of bin walls, in 13 days of two shifts each. Pouring on the bins began Sept. 27, and on Oct. 9 they had been poured to their full height. That part of the structure upon which the moving-form method of construction was employed, extends from the top of the bottom slab of the bin to the bottom of the slab overlying the bin, and was poured as a monolith, an average force of 300 men being employed, one-third of whom were divided into three gangs that did nothing but jack up the sliding forms. The elevator is a terminal elevator built by the Fegles Construction Company, Minneapolis, for the New York State Barge Canal, and has a storage capacity in its fifty-four tanks, its thirty-four inner spaces, and its thirty-seven outer spaces or quarter bins, of about 2,000,000 bushels.

The circular storage bins are 20 feet in diameter set on 24-foot centers, are 95 feet high, and are capable of storing 25,000 bushels each. The inner spaces have capacities of 16,000 bushels each, and the outer spaces of 4,000 bushels each. There are five main elevating legs of 30,000 bushels capacity each, three marine legs of 25,000-bushel capacity, two of which legs are being put in now, the third reserved for future installation.

[1] *Eng. News-Record*, Vol. 87, No. 24, Dec. 15, 1921.

The elevator will also have two marine tower lofters of 35,000 bushels, three gallery lofters of 35,000 bushels capacity, and one dryer leg of 15,000 bushels capacity.

The foundation underlying the elevator was put in by the Raymond Concrete Pile Company, New York City. It consists of a 3½-foot reinforced concrete mat resting upon wooden piles driven at an average centering of 2 feet with pile clusters being driven beneath columns.

The bins are 8 inches in thickness made of a 1:1.6:3.2 concrete mixture. Concrete in the columns, the mat, and the slab, is of a 1:2:4 mixture. The reinforcement in the body of the bins is of circumferentially placed flat bars on 1-foot centers. For the first 65 feet of height the bars are ⅜ by 1¼ inches, for the next 15 feet they are ⅜ by 1 inch, and for the remainder of the distance they are ¼ by 1 inch. The bin contacts are usually 2 feet thick, though where greater strength is required they are increased to a thickness of 3 feet.

The contractor had fabricated for special use on this job 580 steel screw jacks to support the sliding forms. The form for each storage section, whether it be a circular bin, an inner space, or an outer space, is rigidly constructed of 2 by 4-in. pieces. Upon this frame the decking is placed. Thus the clip angles support the forms and decking and themselves are supported by the screw jacks resting on set concrete. From the jacks are also suspended outriggers from which workmen apply the finish of neat cement to the bins.

Materials Handling.—One of the interesting features of the construction of the elevator was the manner in which concrete aggregate and cement were handled. All the concrete materials were barged to the site, there being no direct rail connection. The gravel was premixed according to the concrete mixture desired and stockpiled on the site. The plant layout included two hoist towers, each approximately 160 feet high, two aggregate bins, each with a capacity of about 65 cubic yards, and an elaborate belt-conveyor system. The aggregate was stockpiled at the north end of the site and the cement shed was built at the southern end. A belt conveyor ran from the aggregate stockpile to the first bin situated about 100 feet from the end of the elevator and then across to the other bin situated at the same distance from the southern end of the elevator. Likewise the belt conveyor from the cement shed ran from the shed to the first bin and then to the north end of the elevator. For the aggregate conveyor there was a two-way spout which discharged either into the near materials bin or carried on across the intervening 200 feet to the other materials bin. Likewise cement was sent from the cement shed to its near materials bin where workmen took it off or allowed it to proceed to the farther bin where it was discharged. In this manner each of the two mixers was kept continuously supplied with concreting material from one stockpile of aggregate and the cement shed.

From the hoist towers, the concrete was handled through either one of two movable hoppers, each of which was set in the approximate center of one-quarter of the floor area of the elevator bins. From these four hoppers the concrete was wheeled in buggies to its place in the wall. About forty-two men were all that were required to pour the concrete on the top of the bins, and the number of men included in the construction work when the pouring of the bin walls was in operation was about 300. Three crews of about thirty-five men each were kept continuously employed jacking the sliding forms, the jacks being elevated about 1 inch at a time. The force of 300 men included ground men, carpenters, and those handling steel. This job is one of the few large ones on which numeral steel reinforcing bars have been used, and the contractor's engineer took occasion to remark upon the ease with which identification of numeral steel could be made by the average workman, thereby facilitating its placement.

Fig. 246.—Norfolk's new municipal grain elevator. This reinforced concrete structure, completed in 1923 with the pier adjacent thereto, at a cost of $5,000,000, represent the very last word in modern grain elevator construction. It is proving a great factor in developing new tonnage for the port, has a storage capacity of only 800,000 bushels based on a rapid turnover, by loading vessels rapidly.

H. G. Onstad was the engineer, and J. B. Fowler, the superintendent, in charge for the contractor. The work was done under plans drawn in the office of the State Engineer of New York. Edward W. Anderberg, Senior Assistant Engineer of the State Engineer office, supervised the work for the state.

The Norfolk Municipal Elevator.—Realizing the importance of grain in building up general cargo liner traffic, the municipality of Norfolk, in 1923, commissioned for service a grain elevator of great speed and completeness, in technical detail claiming many innovations. The capacity of the silo is only 800,000 bushels, but it is built for rapid turnaround so that this reservoir should be sufficient for some time to come. With the general idea of the nature and the equipment of an elevator in general, a little more discussion of some of the wharf layout features of the Norfolk elevator should be instructive (Fig. 246).

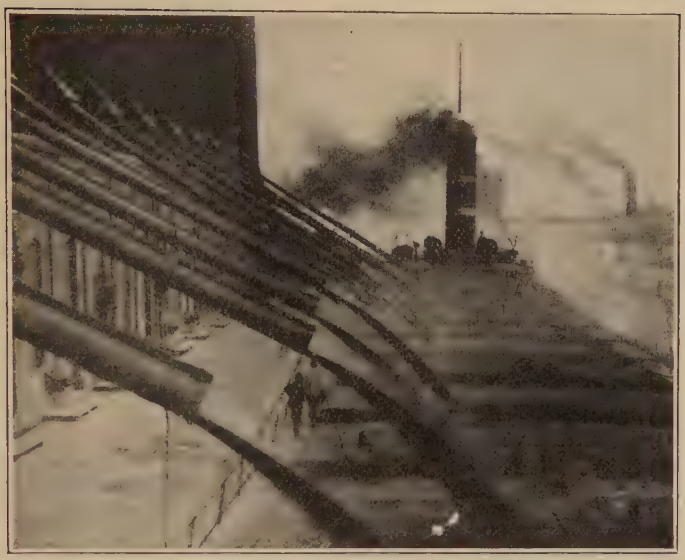
Track Arrangements in Norfolk.—Great care has been taken to lay out the tracks serving the elevators so that one set of working tracks will hold enough cars for a day's work. This obviates idle time to the working force of the elevator that would otherwise arise from shifting cars during working hours. An electric capstan moves up the string as each car is emptied.

Grain scrapers, not car dumpers, are used to discharge the cars. In most elevators the box car of grain is run onto a cradle that tips the car and dumps the grain into a pit from which it is taken to the top of the

FIG. 247.—Grain car dumping cradle at the Port of Portland, Oregon.

elevator by bucket conveyors. To unload the car, the tail-boards are knocked out and the car racked to an angle of some 15 or 20 degrees, and most of the grain flows out by gravity. The rest is shoveled (Fig. 247). At the Norfolk elevator the car is not racked, but a scoop drawn by a cable and electric drum is used to shovel the grain out of the car into the pit.

Location of the Elevator with Respect to the Ship.—The Norfolk elevator is located directly upon deep water with galleries extending in either direction. This is not usual, it being customary to place the elevator some distance from the waterfront and move the grain through gallery bridges to the ship-side gallery from which the grain is tripped into the loading spouts. This practice at Montreal, Quebec, Boston, Portland, and other points is to permit the waterfront space to be used as a general cargo wharf. The Norfolk elevator is placed at the water's edge in order to load one ship at a time very rapidly. This is done by accumulating the grain in large bins or pockets similar to those described in the handling of ore from which the grain flows by gravity directly into the ship's hold



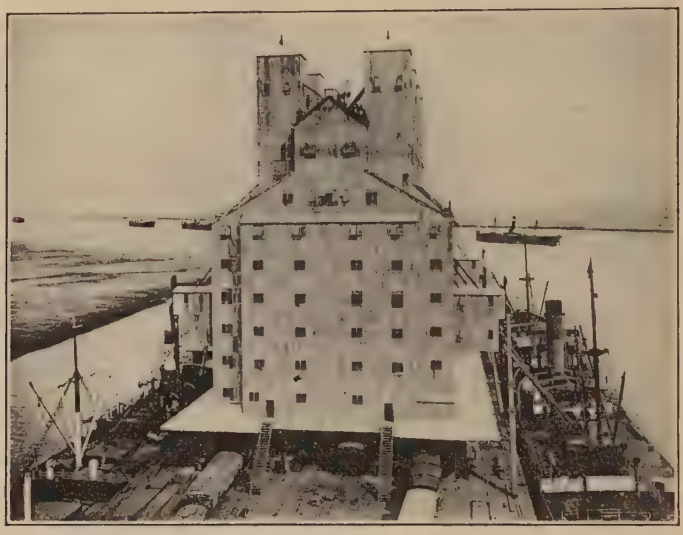
(*Photograph by the author.*)

FIG. 248.—Great Northern Railroad grain elevator at Duluth loading oats. The loading spouts capable of 1,000 bushels the hour were not running at full capacity when photographed, as loading was almost finished.

(*Photograph by the author.*)

FIG. 249.—An older grain elevator of the Great Northern Railroad at Duluth, Minnesota, same as Fig. 248.

through large spouts. It is possible to load a ship in a very short time in this manner. This does not prevent two other ships from being served at the outer end of the quay wall by means of the usual conveyor gallery and spouts. At the Head of the Lakes, the long, all-hatched, trough



(*Courtesy of the Pan American Union.*)

FIG. 250.—Export grain elevator of the Southern Railway at Bahia Blanca, Argentina. Note grain in bags from interior.

FIG. 251.—Grain shipping elevators at Buenos Aires.

type of Lake freighter is loaded directly from the granary through spouts (Figs. 248 and 249).

At Norfolk, the same principle is applied, but owing to the four hatch openings of ocean-going vessels, the direct loading spouts are considerably

larger than in the northern lake elevators. In the Norfolk elevator the ships lie in a specially constructed slip dredged for the purpose and no effort is made to serve a vessel with grain and general cargo simultaneously.

Ship-side Elevators in South America.—The predominating grain exporting ports of South America locate the elevator at ship side and discharge directly into the vessel with no regard for general cargo, as shown in the examples from Bahia Blanca and Buenos Aires (Figs. 250 and 251).

Grain Piers.—The pier is a more economical form of landing than the wharf parallel to the waterfront in handling grain. As there is no transit storage requiring a pier shed in the case of grain, the pier may be long and only wide enough to carry the machinery for handling, consisting of belt conveyors and elevating and lowering spouts, which require very little width. The pier may be as long as the longest vessel using the facilities. The movement is in a straight line from the pier across the marginal street to the storage elevators at the upland.

In fact, at Bremen, where the quay system has been followed in the other portions of the harbor, the grain-handling section was built with a series of piers. These piers handle grain between ships, barges, lighters, railroad cars, and elevators. Transfer from ship to canal barge, at Bremen, is made not in midstream, but over a transfer pier by means of pneumatic transfer elevators which move along the pier to points opposite the hatches as any other crane would do.

Dust Explosion Hazard.—A great menace in grain handling is the dust explosion. Such explosions are liable to occur during any part of the handling process from the thresher through to the ship's hold. Large quantities of dust with a large proportion of fine chaff and hulls, if mixed with air in the proper proportions, will not take fire by spontaneous combustion, but if ignited by a spark will explode similar to a gasoline mixture with air in an automobile cylinder fired by an electric spark. Messrs. Price and Brown in their study of dust explosions, also the study of the United States Department of Agriculture, have led to some very definite figures with regard to this hazard. According to the Department of Agriculture's report, there have been 253 dust explosions recorded in the United States and in foreign countries, and in 60 of these 398 lives were lost, and in 77 of them, 668 people were injured. In 120 of these explosions, the property loss was over $30,000,000.

A theory has developed that the force that wrecks a great structure with a detonation that can be heard sometimes as far as 25 miles, in which great blocks of concrete or other débris may be thrown as far as 2½ miles, results primarily from a series of explosions. The first, or local explosion, is due to the ignition of streams of dust and air by a flame of some sort. This dust may be called active dust. The first explosion shakes loose all

the static dust collected on floors, ledges, window sills, and other points where dust may accumulate, making a second explosion of greater violence when all the dust in the entire building is shaken up and ignited.

To avoid dust explosions, there are two distinct lines of effort, the first to remove the dust itself as a cause of the explosion; the second to prevent ignition by flame or spark. The first method that is followed in modern construction is to pour concrete in such a manner that there are no ledges or other projections upon which dust may accumulate and to install vacuum cleaners and suction ventilators to remove the dust. To avoid the spark that sets off the charge, the first precaution is against smoking and matches, then against open flames and naked lights of any kind. In this, great attention must be given to the proper installation, laying and enclosures of electric wires, and the necessity for all electric light bulbs to be double glass variety with wire protection to guard against breaking. Care must be exercised to see that sparks from motors, switches, fuses, short circuits, electric apparatus, or sparks from static in belting fans, driving shafts, and the like, do not occur. Also, choke-ups in elevator legs causing the belt to rub and overheat the pulley may form a spark or heat that will ignite the dust in the leg. With proper and thorough precautionary measures, the dust explosion hazard should be reduced to a vanishing minimum and insurance rates should come down accordingly.

Grain Loading Records.—The records in grain loading are notable. Port Arthur claims the record for rapid loading from the exploit in 1922 when a Lake freighter was loaded with 325,000 bushels in 9 hours. The same vessel had been loaded in Duluth with the same cargo in 21 hours. In the infancy of Port Arthur some 22 years before, the port's grain trimmers would load a lake carrier with 100,000 bushels in anywhere between 12 and 24 hours. In November, 1922, two steamers were loaded with 776,000 bushels in 14 hours 45 minutes. A smaller vessel, taking 100,000 bushels of wheat, was loaded in 4 hours and 10 minutes.

Fast Loading of Ocean Vessels.—One of the new ports that has been coming to the front with its grain elevator is Portland, Oregon. According to a report of November, 1921, in the initial trial of the plant at Municipal Terminal No. 4, the Shipping Board steamer *Abercos* loaded bulk wheat at the rate of 27,000 bushels an hour. The *Abercos* loaded a total cargo of 7,008 long tons of bulk grain and 738 tons of sack grain in 38 hours, the actual time of the elevator loading the bulk grain was 31 hours. In this terminal the elevator is removed from the waterfront and the loading is done from overhead conveyor galleries above a general cargo wharf.

DISCHARGING GRAIN FROM SHIPS

There are two special types of grain-discharging machinery, the chain bucket conveyor and the vacuum or pneumatic or suction methods. The marine leg, as it is called, may be either of a pneumatic or bucket conveyor type. Bucket conveyor is preferred for stationary or quay discharging; while in Europe the pneumatic elevator is used on the quay as well as on floating equipment. The word stationary or fixed is used guardedly because the marine leg itself in most cases moves along fixed or stationary tracks on the wharf. A typical modern marine leg is added to the equipment of the public grain elevator of the Board of Port Commissioners at the port of New Orleans at an approximate cost of $300,000 (Fig. 252).

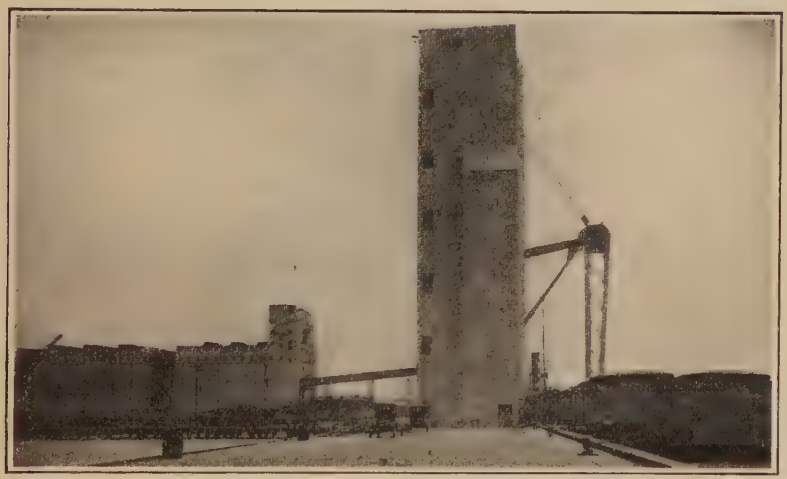


FIG. 252.—Marine leg at New Orleans with unloading capacity of 15,000 bushels per hour discharging bulk grain from a Mississippi River barge.

The Marine Leg Addition at the Port of New Orleans.—This marine leg has an unloading capacity of 15,000 bushels of grain the hour, which together with the present pneumatic unloading system now gives the Public Grain Elevator a total unloading capacity of 21,000 bushels per hour.

This facility was designed especially for use on the Mississippi River with its variable water stages and also for the unloading of the various types of river barges now carrying grain to New Orleans, as well as for all eypes of ocean-going vessels calling at this port.

The grain is elevated from the barges or ships by means of a bucket conveyor operating in an enclosed steel lofter. This lofter is suspended from a boom attached to a crosshead which can be raised or lowered or moved horizontally to take care of the various stages of the river, the

variable heights of the vessels, and the locations of hatches. The grain, after being elevated by the lofter, is spouted by gravity to a system of conveyor belts and lofters which carry it to the main elevator, a distance of 1,300 feet from the marine leg.

The marine leg is equipped with all modern improvements common to such facilities elsewhere, with a number of additional improvements such as an interlocking system of all lofters and conveyor belts, which automatically stops all machinery should any conveyor or lofter cease to operate. All motors are equipped with automatic starters and solenoid

(Courtesy of C. of E., U. S. A.)

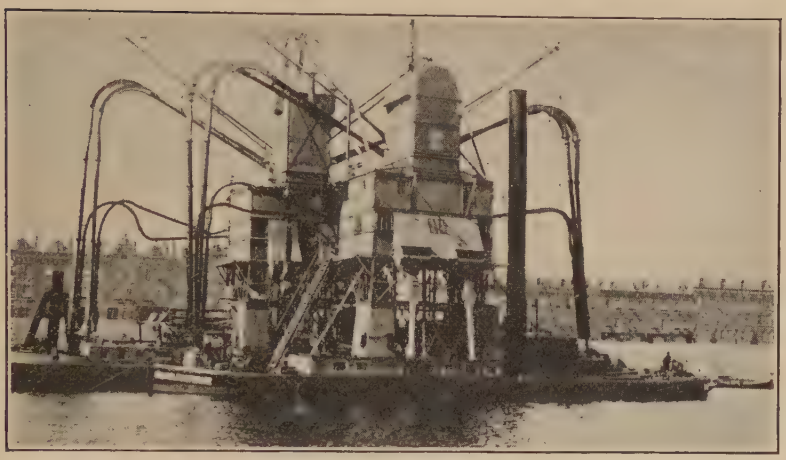
FIG. 253.—Rhine barges discharging grain at the marine leg at Ruhrort.

brakes, and each operation is controlled by an individual motor. Automatic shovel machines are used to draw the grain from inaccessible parts of vessels to the lofter. The wharf at this marine leg is equipped with electrically operated capstans for use in docking and moving vessels. This feature is a distinct advantage in moving non-propelled vessels.

This is the first marine leg to be constructed on the Mississippi River, and the only one in America equipped with a combined horizontal and vertical movement of the crosshead.

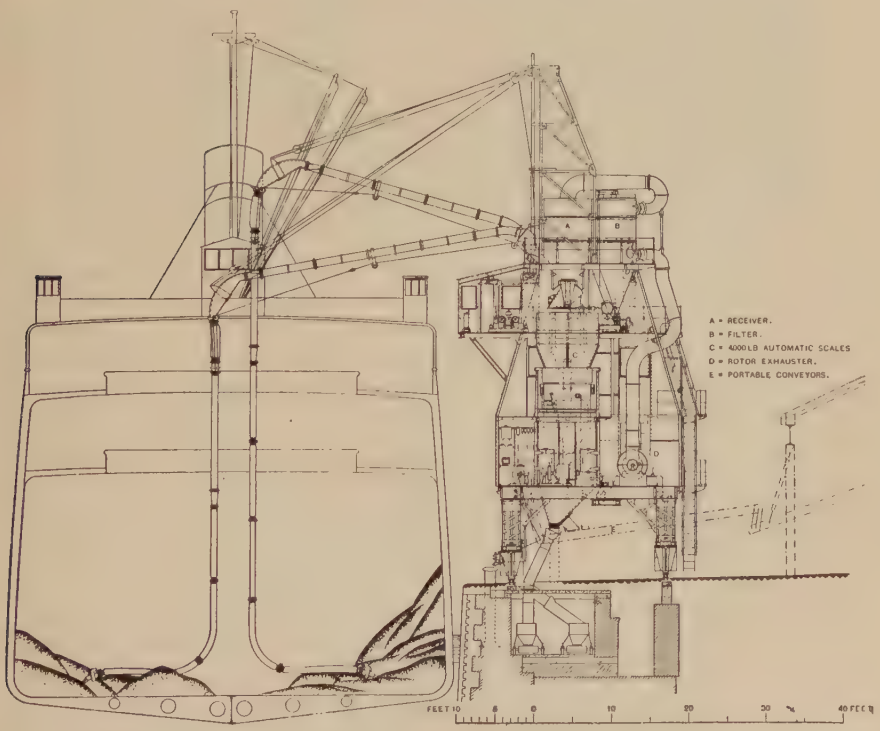
Marine Legs at European River Ports.—The grain unloading marine leg is common at the numerous river ports of Europe. Grain barge traffic along the Rhine, Elbe, Danube, and other streams and canals is very considerable (Fig. 253).

Pneumatic Elevators in Europe.—In the introduction of all modern port equipment, follows the struggle of the vested waterfront interests that endeavor to prevent the introduction of such improvements because of the false apprehension on the part of the men that they will lose their jobs (Figs. 254 and 255).



(*Courtesy of C. of E., U. S. A.*)

FIG. 254.—Two Rotterdam pneumatic floating elevators going to work.



(*Dock and Harbour Authority, November*, 1923.)

FIG. 255.—Quayside elevator. Many of these have automatic sacking and weighing machinery, delivering sacked grain direct to box cars.

One of the first great continental ports that tried to use the pneumatic elevator was Antwerp. However, organized labor prevented its use. Rotterdam then decided to use the efficient modern methods, and set aside a fighting fund of 400,000 guilders ($160,000) with which the stevedores were finally beaten. The grain center moved to Rotterdam where it has remained ever since, with little chance that Antwerp will regain it, although modern equipment finally was installed there also.

Rotterdam as a Grain Port.—One Dutch periodical *Cerealia* says that some surprise has been expressed at Rotterdam's being able to compete successfully with Antwerp, Emden, Bremen, and Hamburg for the grain traffic despite the unfavorable foreign exchange. The explanation for this seeming anomaly is furnished by Rotterdam's superior grain-handling equipment, which makes it the cheapest port in the end.

Rotterdam possesses twenty-eight grain elevators, while Antwerp has only sixteen, Hamburg twelve, Bremen four, and Emden two. It is claimed that in the rapid discharge of grain in bulk, Rotterdam exceeds all other ports.

Ship and Barge Transfer.—Transshipment from barge to ship will grow in the United States as the waterways come into their own as transportation lines for bulk cargo. In time we should develop at New York and at New Orleans transshipping points for grain as efficient as those of Hamburg, Rotterdam, and Antwerp.

Direct transshipment from barge to ship or *vice versa* by means of powerful pneumatic elevators is the most economical movement for several reasons. (1) The movement of the cargo grain from and to the interior by means of large capacity barges is more economical than by rail. (2) When barges are used, in particular tow barges not made more expensive by propulsion machinery, the expense of holding the barge for several days as a warehouse for the grain is not excessive. To a large extent this saves the additional expense of temporarily storing the grain in elevators pending shipment. If this storage is not too long, reconditioning in an elevator is not necessary. (3) The cost of loading overside by means of pneumatic elevators is low, as the distance of travel of the cargo is short. In the case of tramps loading in stream, with free mooring-post wharfage, the item of wharfage and lighterage would be saved. Four floating elevators working from both sides can transfer 3,000 tons (112,000 bushels) of grain from barge to ship in a 9-hour day.

In the main the grain carriers are liners, taking on other cargo and passengers at piers. The loading is therefore only possible from the water side. However, the economy of bringing the grain barge alongside the liner and transshipping from barge to ship is obvious. The operations of "warehousing" the grain in an elevator and then lightering to the steamer are saved by the barge-to-ship movement. The movement is somewhat analogous to the freight car-ship-side movement, but even

better than this, as no expensive transit shed is required. In the case of general cargo the freight car may be brought alongside the shed opposite the ship, but the freight must be piled in the pier shed ready to be loaded into the hold in a rapid and orderly manner. In the case of barge-ship transfer of grain this movement is also eliminated and the ideal of all freight movement is accomplished, which is from the source in the interior to alongside the ocean steamer without breaking bulk and rehandling.

The first requirement is that there be ample barge harbors where the barge may be held at moorings until the ship is ready for the cargo. This may be several days or a week. At Hamburg the Moldau Harbor of 70

(*Photograph by the author.*)

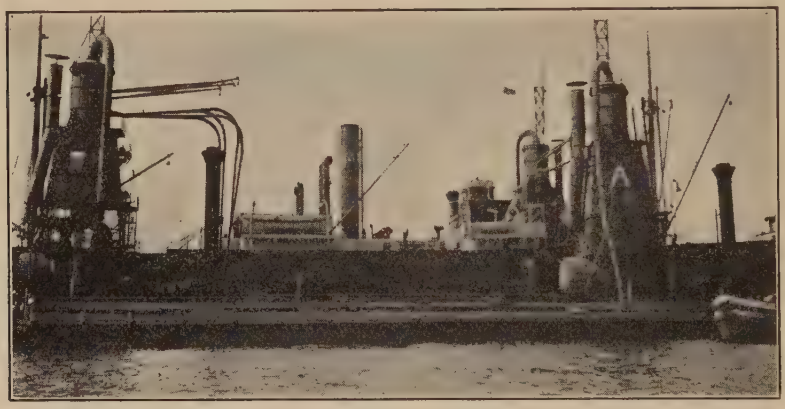
FIG. 256.—A basin at Hamburg with grain elevators discharging from a steamer to barges, on the left under the crane, the *Leviathan* at the fitting out quay being completed.

acres is built and operated as this kind of a terminal. That is, there are warehouses and sheds and other terminal facilities especially for barge traffic in general, and in addition, a large water area to accommodate barges waiting for the ship. The economy of this system of short-term storage on the barge to save rehandling of the grain is a cogent argument in favor of tows and not self-propelled barges for this class of freight. If not unnecessarily expensive, the barge acts most efficiently as its own pier shed. This rule of tow vs. self-propulsion, however, does not apply to package freight, where oil motors and power plants are the ideal equipment.

The pneumatic grain elevator, both floating and located on the quay wall (Fig. 255), is the usual practice for grain unloading in London. These pneumatic elevators are a great size in capacity. They usually combine automatic weighing and sacking machines so that the grain drawn up through the tubes from the hold of the ship is delivered in bags of uniform weight over belt conveyors to the waiting box cars.

At the port of London, there is another variation. The grain elevator is mounted on a parallel pile wharf or jetty between the quay and the ship, the space between being occupied by river barges and lighters. The very long boom cranes on the quay can reach across the intervening jetty over which the grain elevators move. The elevators themselves discharge either to conveyors that go to the granaries, or into sheds that load the small craft lying between the jetty and the quay wall, or directly into these barges.

At the ports of Antwerp, Rotterdam, and Hamburg, having extensive inland water connections with the interior, practically all transfer of



(*Photograph by the author.*)

FIG. 257.—A grain ship at mooring-posts discharging into two Elbe barges of 500-1,000 tons capacity. Four pneumatic elevators will transfer 112,000 bushels in 9 hours.

grain is from ocean ship directly to canal boats by means of floating elevators of large capacity (Figs. 256 and 257).

The Pneumatic Copra Unloader.—The principle of the pneumatic unloader is applied by Leland Rosener to an equipment at the Howard Terminals, Oakland, California, for the handling of copra. The machine consists of a special blower driven by a 100-horsepower motor, the suction of the blower operating on a large drum from which an 8-inch pipe line is lowered into the hold. This pumping equipment is loaded on a flat car that moves along the waterside track of the wharf. Box cars on track No. 2 are employed to receive the copra. The principle can be applied to any free-flowing bulk commodity of a specific gravity that will permit it to respond to the vacuum. This method is familiar to anyone who has seen a country cotton gin in operation.

Linseed can be handled in bulk like grain.

CHAPTER XVII

THE INDUSTRIAL HARBOR AND UPLAND DEVELOPMENT

It is hardly possible to discuss the industrial harbor without discussing upland development. Each involves a close study of land values. The desirability of property for industrial enterprises is determined by its proximity to centers of commercial intercourse and to means of transportation. The forces involved are most easily seen in the case of passenger traffic. We have two illustrations in New York. One of them is the "City" or Wall Street district of high land values where it is desirable to be within walking distance from the centers of commerce. Here the increase in land values made essential better utilization of the land by the application of more capital in the shape of higher buildings. The ability to increase the return on a given plot of land by the application of more capital and labor in the shape of higher buildings again increased the value of the land by increasing its ability to yield a still greater return. The value of land depends upon the income it will yield in connection with the application of capital and labor. This reciprocal action between the additions of capital improvements and the increase in the value of the site of the piece of land has driven the ground rent of property in immediate proximity to the center of finance to unheard-of heights quite irrespective of the fact that there is plenty of cheap land in the Dakotas. The land, together with the capital applied to it, has been able to satisfy the demand of more individuals who desire to be within walking distance of Wall Street.

Likewise the converging of rail, surface bus, and subway lines has increased the accessibility of the neighborhood of Forty-second Street and Fifth Avenue for shoppers and travelers. Therefore the desirability of this location for buildings devoted to clubs, hotels, shops, and offices has increased the demand for, and price of, property. The application of capital for improvements to the land in the shape of luxurious hotels, shops, the Buyers' Club, etc., has been profitable. The foundation of the land value is the accessibility of the land because of transportation facilities which make it more productive and therefore more desirable.

Industrial sites are less conspicuous examples of the operation of the same laws of site rent. An undertaking of a manufacturing nature desires to be both at the center of commerce and at the point of transportation accessibility.

In order to understand the problem of upland development in the following pages the theory of land value must be kept well in mind in order to evolve the most practical plan of harbor layout.

First, we have the productivity theory of land value. This theory has just been pointed out by the two New York examples. The value of land is determined by the amount which one piece of land as compared to another piece of land contributes to the value of the product for which the piece of land is used. It is apparent, however, that the land itself becomes more productive with the judicious application of capital. However, with the same application of capital in the shape of buildings one piece of land, because of its location, will yield a greater return than another piece of land, and therefore will be more valuable, because of its greater productivity. The demand for that more productive piece of land will be greater and the price which one is willing to pay for it will be greater. The price will not reach a figure that will not return a fair income from the capital and land (now capitalized in the price) working together. There is, therefore, a limit to the price of land set by the productivity of that land as compared with other land.

Likewise, land value is said to be determined by the cost. In the case of site rent—the value due to location—the cost of building the means of communication which will give the land the desired accessibility determines the value of the land. The supply of land with improved traffic conditions will be influenced by the cost of creating the means of transportation. In fact, the cost of creating the desirable conditions will put a very positive check on the supply.

Now, price is determined by supply and demand, but the demand will not increase the price of land beyond its productivity, and the supply will not be decreased until the price falls below cost. The answer to the question, Will it pay? depends on these two limits.

Also the use to which land is put ranges from the intensive application of capital, such as the Woolworth Building or the Hotel Commodore, to the extensive use of the land for a shipyard, a gas works, or other industry which requires much ground room. Of course, the shipyard would like to locate on the west side of Manhattan, but the return is too little to cover the ground rent, as it is determined by the more productive enterprises at that location. The more extensive enterprises, therefore, must move away from the centers of commerce, desirable though that location may be. The cost will otherwise exceed the productivity.

Keeping these principles in mind let us consider the case of the industrial harbor. The location of industry within the corporate limits of a municipality or a state is of great indirect advantage to that political unit. The industry pays wages and salaries to many people who buy or rent homes and increase land values, which also increases the land tax income. The salaries and wages are spent in the shops and markets of

the community, which increases the volume of business done, which again increases the income of the municipality, through the income and land taxes. The bank clearings are increased in the same manner and with the same effects of quickening business and increasing the income of the local government by various direct and indirect methods of taxation.

One good way to attract industry has been to offer advantages of location with regard to transportation. In the United States the number of railroads entering the city has been the drawing card. In Europe the municipalities and states have long since considered the rail transportation, under government ownership or control, as a matter of course, and have applied themselves to the development of water transportation as an additional attraction. The municipalities have gone to great expense to build and equip water transportation facilities in connection with industrial building sites. A glance at any of the maps of recent river ports or seaports in Europe will show the extent of the *terrain industriel*, or *Industrie Gebiet*, or whatever its name may be. The Germans have gone farthest in the actual execution of industrial harbor works, but the planned extensions of Antwerp, Bordeaux, and many other cities include vast areas of upland destined for industries. The industrial port is primarily a canal adjunct even at the seaport because the productivity of deep waterfront by intensive development is too great to admit of its use for general industries.

The European municipalities have sought to promote the common welfare by building the necessary harbor works and attracting to them the heavy industries which are most interested in low freights. For instance, when the International Harvester Company was about to build a large factory in Germany, the various municipalities sent their committees to present the points of advantage of their municipality as the most economical location for a large factory. Magdeburg offered an extensive area on the Elbe to the north of the city with a municipal wharf improvement included. This location would have been midway on the great Elbe water thoroughfare from the port of Hamburg to Bohemia, and also in the very center of a great railroad net.

But there were competitors. The town of Neuss had tapped the Rhine water highway and built canal side arms and basins giving direct waterfront to many acres of industrial sites. This location gave canal barge access to the port of Rotterdam and to the great coal fields. In other words, the accessibility of raw materials was better at Neuss; at Magdeburg the distribution of the finished products was better. From this analysis, other things being equal, the Neuss location was better. Raw materials have far less specific value, that is, greater weight and low value, and are less able to bear the traffic expense. But other things were not equal. The town of Neuss in addition offered the terrain at a

low figure and rebated the taxes on the enterprise for 10 years. It is usual in these municipal industrial harbors to lease the harbor sites for a term of years and not to sell the land. The Neuss salesman cut prices, but got the big industry to locate at his city. Municipal salesmanship is as important as any other branch of the science of how to get the signature on the dotted line.

Now how about Neuss? The return to the city from the indirect result of the industry locating there is great. We saw this fact above. But lease rentals from the industrial terrain located at the expensive harbor basins do not pay interest and maintenance on the large investment. The deficit is made good every year out of the taxes, and the harbor is an expense in the city budget. Few if any of these municipal industrial harbors have been self-supporting. They seldom have paid interest on the investment and maintenance. Even if the various municipalities have continued to build and operate industrial harbors at a loss because the indirect value of the industries attracted to them has been a benefit to the community in general, the question arises, Is this loss actually necessary?

In the United States we have not yet arrived at this stage of the development of the municipal harbor except in the case of a few seaports. This backwardness in America may be an advantage of importance. Our lack of progress in this connection may be our good fortune. As the situation of the industrial harbor is studied, it will become apparent that it should not be necessary to operate such an expensive institution at a loss if it be properly designed and equipped in the beginning. With the opening of the Barge Canal, and the development of the long-neglected possibilities of the Mississippi as the greatest water highroad in the world, the question of the industrial river port will be acute. The question already is acute in the case of the Jamaica Bay Improvement, that of Newark Bay, of Lake Washington at Seattle, and many others.

The problem is how to tap the upland. It is how to extend the benefits of the waterfront to the maximum distance inland. It is axiomatic that the deep waterfront must not be misappropriated for any other use than that of transshipment. Shipbuilding is an exception. The degree of the success of this effort to extend the benefits of the water connection to the upland determines the possibility of spreading the cost of harbor works over a sufficient area of land to make the cost of the area less than the productivity. The municipality must bear the burden of the difference or no industry can afford to locate there. If the cost of the terrain can be lowered, the city may save money to carry out other important works. This relation of cost of construction to area served in relation to the mechanical connection which may be established is expressed in the following formula:

The proportionate cost of harbor improvement of a given unit of waterfront varies inversely as the depth of the piece of property served by the waterfront.

If a piece of waterfront cost $100 per linear foot to improve (dredging of basins and channel, retaining walls, transshipping machinery, etc.), and the adjacent upland is 100 feet deep, the portion of cost per square foot will be $1. If the depth be 200 feet, the proportion will be 50 cents. If it be 1,000 feet it will be 10 cents providing the additional upland can be made accessible at low expense.

However, the cost of communication with the upland also increases with the distance. The result of the two forces is a formula something like this:

$$X = \frac{(l \times L) + (M \times D) + C}{D \times l}$$

X = cost of each square foot of upland area.
l = length of waterfront served by mechanical equipment.
L = cost of harbor works per linear foot of waterfront.
M = cost per foot of mechanical connection between waterfront machinery and upland.
D = depth of the piece of property measured from the water in feet.
C = original cost of land.

It is evident from the nature of the equation that there will be decreasing cost to the point of diminishing returns. If plotted on a graph, the cost of harbor upland would give a U-shaped curve. When the cost of mechanical connection ($M \times D$) together with the original cost of harbor works grows greater as D is increased, instead of less, the economic limit of the depth of the upland has been reached. The variable is M. If means can be designed with such engineering skill that $M \times D$ remains relatively small, D may be increased to several hundred feet before diminishing returns become evident.

The problem therefore is to increase the depth of the property as compared to the waterfront by mechanical means of communication.

Character of Industries Interested in Water Connection.—Before discussing the engineering problems involved it may be well to consider for a moment the character of the industries benefited and attracted to the industrial harbor. Any industry which utilizes large quantities of bulk material of a low specific value finds the element of transportation expenses the greatest problem of the business. Coal, ore, sand, clay, cement, pig iron, cotton, and petroleum are the most important bulk commodities. Such industries as smelters, gas plants with coke ovens, electrical power plants and foundries, cement works, calcium carbide works, and also higher grades of production such as heavy machinery, pipe, structural steel, boiler factories, building materials of all sorts,

brickyards, tile works, glass factories, and countless similar industries require large quantities of fuel and materials.

A location which affords easy transportation by both water and rail will have an increased value in proportion to the saving in the final cost of production which this location affords as compared with other less favorably located industries.

The heavy industries are the ones which the various municipalities desire to attract by building industrial harbors. It is also a farsighted policy to attract the industries whose products are the foundation for more refined manufacturing. If by reduced transportation costs it be possible to produce the half products at less cost, these half products which are the raw materials of the lighter industries will be available at lower cost. The heavy industry at the well-developed industrial harbor will be able to quote lower prices on half products and thereby make it of decided advantage for the light industries to locate at the same town in order to be at the source of the needed materials. This is the economic foundation for the rapid growth of Gary, Indiana, far beyond the direct requirements of the United States Steel plant.

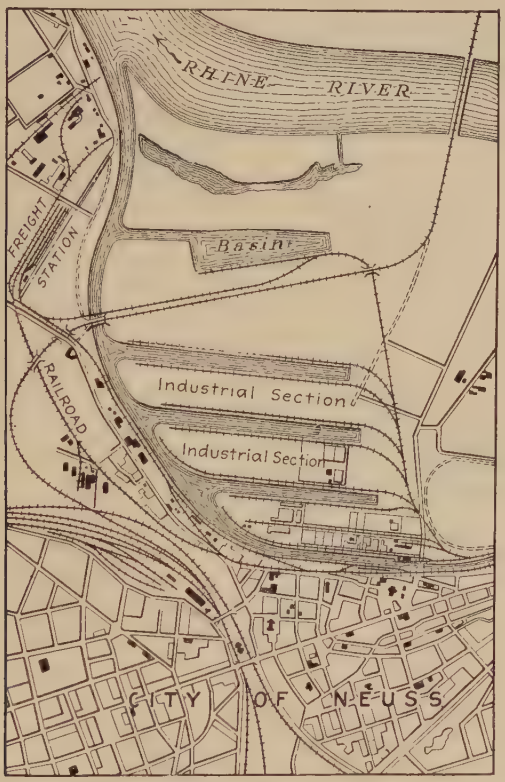
The Mechanical Problem of the Upland.—There is a decided difference between handling the materials for an industry for shipment and handling the products of a mine. The difference is in the quantity which must be handled within a short space of time. No ordinary industry needs to fill a 12,000-ton ship in 39 minutes or discharge it in 2½ hours. A plant which requires this amount in a day or even a week is a large one. Many large plants do not use more than 50 tons of fuel and material an hour. The problem is therefore not so much one of speed and quantity, as one of cheapness and the minimum of supervision.

The problem of how to hold the boat for the shortest possible time is also not of first rank importance as in commercial harbors or Lake navigation. The reason is that industrial plants, except the very large ones, do not receive their materials or ship their products in steamer-load lots. The usual vessel is a canal or river barge or harbor lighter. The capital investment is not so great per capacity because these barges and lighters are towed and not propelled by their own power plant. They are brought alongside the wharf of the industry and left there for loading or discharging. This may proceed at a leisurely rate without the interest on the investment becoming a controlling factor. The industrial wharf is usually a barge or lighter wharf. A notable exception may be made in the case of the great steel plants on the Lakes, using the large Lake steamboats described above. (Chapter XIV.)

Side-arm Canals.—The usual method of opening the upland in municipal industrial ports has been to tap the main waterway by a system of side-arm canals, wherever the nature of the land makes this possible. Such side-arm canals must be as deep as the fairway, for they

are to accommodate the same barges that navigate the main waterway and river craft. At a seaport the depth should be sufficient to accommodate lighters.

The expense of such harbor construction differs widely according to the geology of the country. In low, marshy land, such as the Hackensack meadows, the Newark Bay territory, or the flats about Detroit, it is about as simple to run canals and fill the land with the spoil as any other method of reclamation. Therefore, with easy dredging, the system is



(From *Le Génie Civil*, Paris Mai, 1917.)

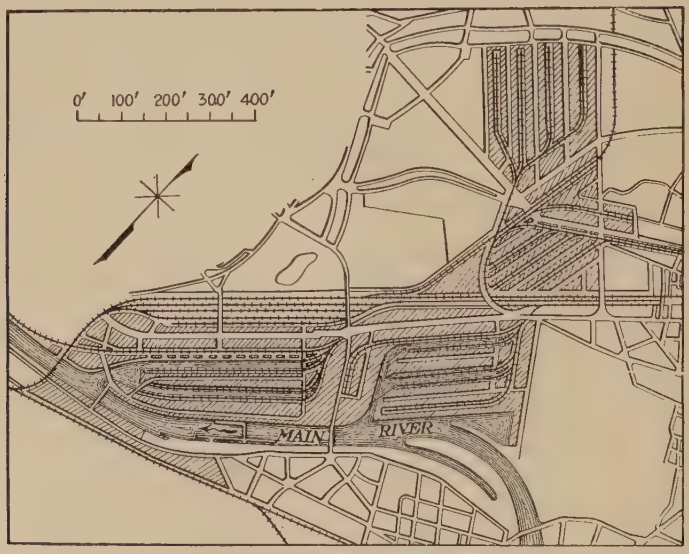
FIG. 258.—Industrial and commercial port area of Neuss.

more efficient and cheaper per square foot of territory served than almost any method of opening the upland.

In the same ratio as the difficulty and expense of constructing side canals increase, so also does the necessity of making the water connections farther apart so as not to overload the cost of the industrial area served. The connection with the upland by mechanical means is increased in length as the canals are built farther apart. The practice of too frequent canals, as shown by the maps of famous river ports, involved too great

an investment in harbor works to be economical. The territory served is too small to allow of sufficient diffusion of the initial costs over the area. It is also evident that side canals above the least possible number will not only add to the cost of the works, but will put too much land under water. The loss of space occupied by the canals will bear too large a proportion to the whole and also add to the cost per square foot of building sites.

If dredging conditions permit of frequent canals it may be possible to allow the industries on certain canals to extend their buildings to the water's edge. When the canals are far apart, a marginal way for public use should be left connecting the wharf with the upland. In this case



(From *Le Génie Civil*, Paris Mai, 1917.)

FIG. 259.—Industrial and commercial port area of Frankfort-on-the-Main.

the conveying machinery should not be at grade, but at sufficient height to allow the passage of vehicles under the conveying machinery. Fortunately most conveyors operate normally at a high elevation in order to accommodate stock piles of materials.

When the river port has been built at large expense because of the firmness and elevation above water level of the upland, the industrial terrain cannot be served by canals at all. In this case the port proper, the transshipping point, must be connected by railroad tracks and the connection with the waterfront maintained by cars with switch engines. The map of the river port and industrial area of Frankfort-on-the-Main will illustrate this.[1] The industrial lofts of the Bush Terminals also

[1] *Le Génie Civil.*

follow this system. At the Bush Terminals the industries which are engaged in light manufacturing do not have the same vital interest in immediate connection with the water as, for instance, the many power houses around the Manhattan waterfront, whose need of immediate transfer of coal from barge to bins makes it worth while to occupy even valuable Manhattan waterfront to accomplish a saving in coal transportation. The port should be planned to allow an open wharf frontage for the public, even in such cases.

Bulkhead Connection.—At the port of New York and many others where the difficulty of excavation makes upland development by canals out of the question, where there is a great length of natural shore line, and where the water off-shore is wide enough to allow of pier construction, the upland may be opened for heavy industries without withdrawing the valuable waterfront from its proper function as a transshipping point. The waterfront should carry the usual pier equipment with sheds and transfer machinery for ships. The piers, however, should be placed sufficiently far apart, at a distance of about 300 feet, to allow lighters, scows and barges sufficient length of bulkhead to lie alongside. The bulkhead would then be equipped with the necessary conveyors, to be described below, which would raise the material above the head room level of the traffic of the marginal street and carry it across this to the industrial territory beyond. Such a system would preserve the waterfront for the intensive transshipping activities and at the same time relieve the industrial terrain from the largest part of the expense of the waterfront development. At the same time it would afford the industries all the advantages of cheap transfer of materials between water carriers.

The Mechanical Devices of Upland Connection.—There are three distinct classes of duty to be performed by the mechanical devices connecting the upland with the waterfront, which are determined by the amount of material to be moved.

Duty *A*, which we may call "heavy," will require the movement of 250 to 350 tons of material an hour. This will require a pair of heavy-duty bridge cranes of the Brown Hoist Fast Plant type, or a Stuart System Belt Conveyor, piler and reclaimer. The industries requiring duty "*A*" are smelters, or iron or steel plants, using great quantities of coal and ore.

Duty *B*, with a demand for the movement of 50 to 100 tons of material per hour, will be met by a cable crane or light bridge crane of considerable length inland and limited waterfront. Gas works, cement works, glass works, etc., will do very well with this service.

Duty *C* (light) will not require a service of greater capacity than 25 to 50 tons the hour. To this class belong all those industries which are engaged in the manufacture of more finished articles. Their chief requirement to be transported by water is fuel. The port area can be

served by a telpher system with movable loop sidings to cover the various fuel piles.

It will be seen that each succeeding group has less waterfront and more upland. There are two reasons for this. First, the heavy-duty industry, by handling many thousands of tons over the waterfront every year, is able to dilute the higher fixed charges of greater waterfront and more expensive equipment, and thereby reduce the expense per ton. Also the higher speed of movement of the material makes it necessary to have the traveling buckets or cars or conveyors move shorter distances and make more trips.

Heavy Duty.—In the case of duty *A* the length of waterfront is far in excess of the length of the two barges for which provision has been made. The equipment for duty "*A*" is the same as that for ground storage of bulk products for transshipment. The advantage is with the Stuart System because of its saving of waterfront. The proportion of upland to waterfront shows a more favorable equation of cost distribution in this system.

Light Duty.—In the case of duty *B* there are other mechanical devices which are far less expensive in ground rent and in construction than any of the above methods. However, owing to the smaller ton capacity the cost per ton may not be less than the heavy-duty outfits handling thousands of tons every day. The problem is therefore a different one. The object is to save ground rent by carrying a small amount of material farther upland.

This may be done by light-duty bridge cranes. A solution which has been very satisfactory in many European installations is the cableway, cable crane, or cable telpher. The general principle is the same as in the Brown Hoist Rapid, the traveling hoist operating a grab bucket (clamshell). However, the bucket capacity is less and the travel longer, and this means fewer trips per hour. Reckoned on a ton-for-ton basis it is much less efficient. The first difference is that the water and plant ends move along the short side of the storage ground while the length is spanned by a cableway (or light bridge) instead of the heavy-duty bridge. Greater depth per linear foot of improved waterfront reduces the cost per unit of space. The possible span of the cableway is much longer for light duty than the bridge. Therefore with the movement of material required to supply only one plant of reasonable capacity the advantage of layout is with duty "*B*." The equation shows a lower total cost of handling material due to the better utilization of the upland. Cables with the capacity of loads of 12 tons and a span of 1,500 feet are not usual.

Light Special Duty.—Duty *C* involves less movement measured in tons, but over longer distances and with more diversified loads. The most important movement, as a rule, is to get fuel in and ashes out. There is other waste or refuse from the plant and sometimes part of the

products of the plant to be moved to barges, scows, or lighters at the waterfront. As long as the size and weight of the loads are reasonably uniform there is no great difficulty in supplying mechanical equipment.

In opening the upland of a municipal industrial harbor the practice has been for the city to build side canals. Therefore, there shoule be nothing unseemly about having the city supply a common telpher trunk line to the waterfront, *i.e.*, an uncommon telpher to be used in common. The side loops would be provided by the occupant of the factory site and also the rolling stock, according to the size and nature of the loads. A cotton merchant would have a set of motor-driven telpher cars to carry cotton, the oil merchant the same with the proper slings for carrying barrels, etc. The rolling stock could be of the man-trolley or of the automatic type.

FIG. 260.—Fordyce installation at Texas City. Cotton transfer from warehouses to ship by overhead trolley.

Mr. John R. Fordyce[1] has built several installations of this character for private companies at Texas City and Mobile, Alabama. The entire principle involved is shown by the photographs and drawings and described in his letter to the author (Fig. 260).

I am enclosing copies of photographs which show the trolley system which was constructed at Texas City, Texas. I am also sending a small outline map and indicating on it the points from which the photographs were made.

From the map and the description which I have copied from the Manufacturers' Record which was made by the Chief Engineer, you can get a very good idea of the structure. The total cost of the double track high line and the extended low lines in the warehouses and wharves was $36,000.

If the cotton bales can be fed up to the base of the incline as rapidly as the high-line conveyor can take them, it would be possible to put over from Compress No. 1 to ship side at the end of warehouses *A* and *D* 14,000 bales of cotton in 24 hours. The maximum speed of loading a ship by the methods now in use is not more than 2,500 bales in 24 hours, so that you can see that we can supply cotton enough to load simultaneously about five ships.

This plan was contrasted with a plan of using an electrically driven telpher which was to operate from the high line only, and two machines picking up cotton at the east end of Compress No. 1 and delivering it to the west end of

[1] Colonel of Engineers, United States Reserves.

either warehouse *A* or warehouse *D*. These were able to handle 2,000 bales in 24 hours, so it would have taken about 7 days to accomplish in that manner what this continuous conveyor system does in 1. In addition to that, the structure of the high line had to be strong enough to support a concentrated load of forty bales, together with the heavy telpher machines. This structure alone, and the two machines, had an estimated cost of $40,000.

As an indication of saving brought about by this conveyor system, it would seem that it costs about 3 cents per bale now to transport over to the warehouses, where it formerly cost 13 cents per bale to load the cotton into railway cars way back at the ladder tracks, then switch it onto the proper lead and switch it then to the warehouse at the wharf. Another thing in favor of this telpher system was that cotton could commence to be delivered immediately after the order to move was given, whereas by the railway car method, it was necessary to load at least five or six cars before it was worth while for the switch engine to move them.

Monorail for Quickly Loading Cotton on Ships at Texas City.—The Texas City Transportation Company has installed a monorail system to facilitate the handling of cotton from the compresses and warehouses to ship side. More than a mile of monorail is in operation, with a capacity at maximum of 10 bales of cotton per minute, or 600 per hour, from compress to warehouse or ship side.

A monorail, as the name implies, is a single light rail over which commodities may be transferred, usually from one warehouse to another or from points in the same building. The rail is ordinarily fastened to steel "I" beams, channels, or wooden beams, and is equipped with a roller contrivance from which are suspended the articles of merchandise, etc. These rollers may be moved by hand, wire cables, or chains, or, in some cases, the track is inclined, the rollers then being operated by gravity.

The monorail system in Texas City is of a special type, and today is the only one of its kind in existence. The system is divided into two sections. First, the low-level lines, totaling about 1 mile in length. These lines are placed in the warehouses or cotton compresses and attached to wooden brackets about 7 feet above the floor. These are feeder lines. Second, the high-level lines, placed outside the buildings and extending over the railway tracks for a distance of 1,200 feet. The low-level lines are connected with the high lines by inclined trackways. The high-line track is about 34 feet high, and is suspended from heavy wooden *A*-shaped frames.

On the high line, about 14 inches above the rail, are two small angle irons which make a trackway for the heavy, endless, ice chain. This chain is fitted with pushers, one every 10 feet, and with rollers similar to skate rollers, also every 10 feet; as the high line is double-tracked, this chain is approximately 2,400 feet in length. There are frequently 240 bales of cotton in the air, all moving at about one-third the rate of a walking person. This chain is operated by a 15-horsepower electric motor. The inclined lines have a similar chain, but operated with lighter motors. One of the tracks of the high line is used for the return of empty trolleys, which are automatically discharged at any desired warehouse, and a retarding motor delivers the trolleys to the low line with a uniform speed. The ascending motor automatically delivers the loaded trolleys to the high line.

The trolley to which the hooks supporting the cotton bales are attached resembles the letter "J," the stem being fastened to two ball-bearing rollers that fit the rail, the crooked part being perforated to permit the passage of a chain with two hooks suspended in equilibrium. On the low-level lines one man is capable of pushing ten bales of cotton, or, by giving each bale a sudden push, he can advance it about 200 feet, so that by stationing men every 200 feet cotton can be rushed to the high line with great speed. With all of the motors in operation, cotton may be delivered to warehouse or ship side at the rate of ten bales per minute, or 600 bales per hour. Each warehouse, as well as each incline, is equipped with switches to divert the empty or loaded hooks.

The greatest future possibility that I see in such a system is that it enables warehouses located back away from the waterfront to be coupled up to the

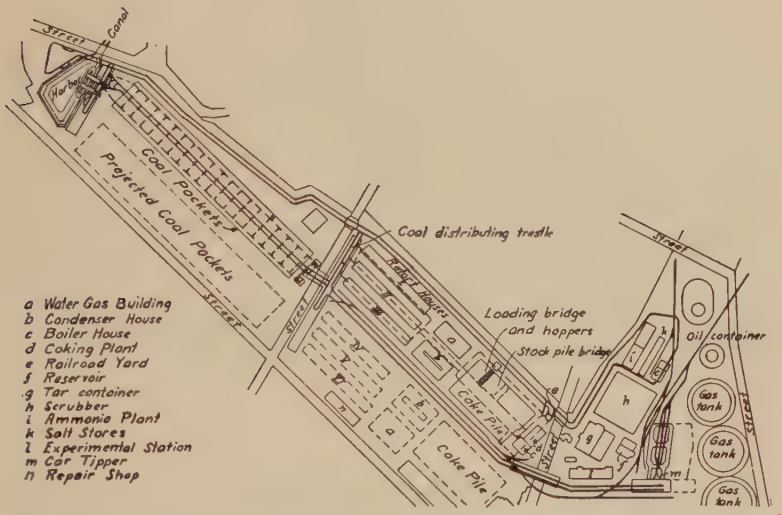


FIG. 261.—Small harbor and extensive upland of the Berlin-Tegel gas works served from small side-arm canal. Connection by means of overhead monorail system.

waterfront by a light, cheap, overhead structure, on which continuous delivery of freight can be carried on above the congested railroad yards and the congested street traffic, which always is present at much used ports.

I am also enclosing a map of a little layout which I got up to be used in the City of Mobile. Here there were three owners of the wharf front, the Southern Railway, the Mobile and Ohio Railway, and the Municipality of Mobile.

The large warehouse area located west of Commerce Street was cut off from the waterfront by the fact that the main line of the Louisville and Nashville to New Orleans passes along Commerce Street, and it was stated that, in order to load a ship anywhere on the waterfront, with material which had been stored in warehouses or which came in by cars over the Southern and the Mobile and Ohio Railway, there was a delay of at least 7 hours, due to the constant interruption of traffic by the passing of trains on the Louisville and Nashville Railway.

Another fact that appealed to the city was that the small piers and warehouses situated on them could be used as unloading platforms and not as storage warehouses. By installing this system of conveyor into all storage warehouses

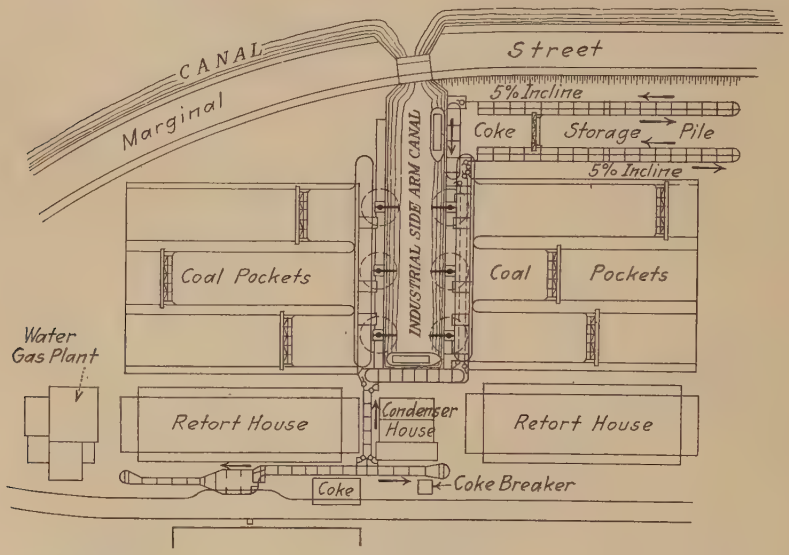


FIG. 262.—Crane unloading and telfer transfer system of a gas plant.

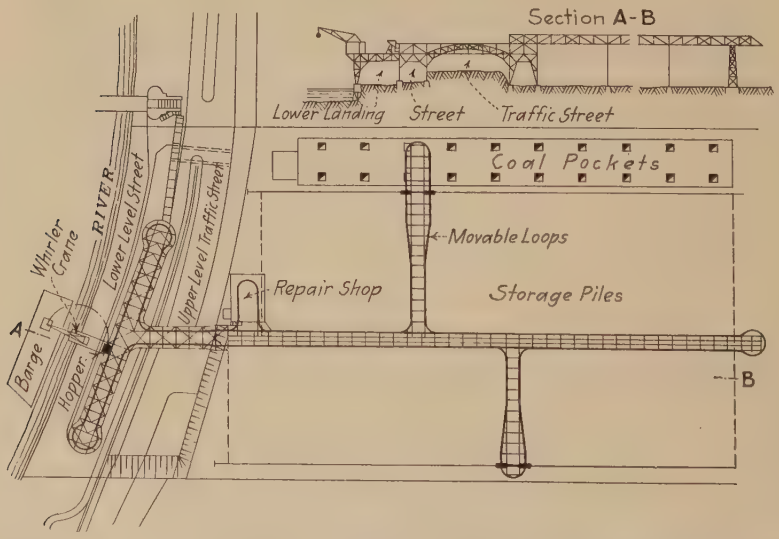


FIG. 263.—Layout for a coal company. Electric telfer with a crane unloader and movable loops.

back in warehouse area, material could be quickly transported to any pier, and in consequence ships loading mixed material could direct their cargoes from various warehouses and not be compelled to change their berth.

This project, however, has been postponed because of war conditions and is not now being put through. It was decided upon, however, by the engineers representing the various interests of Mobile, only after they had visited Texas

(*Courtesy of C. of E., U. S. A.*)

FIG. 264.—View of coal yard at Berlin shown in Fig. 261.

(*Courtesy of C. of E., U. S. A.*)

FIG. 265.—Berlin electrical works' coal unloading plant.

Courtesy of C. of E., U. S. A.)

FIG. 266.—Berlin gas works' coal unloading plant.

City with me and had had an opportunity to see the Texas City conveyor in operation.

(Signed) J. R. Fordyce.

The point to be emphasized is that a municipality which builds a commercial port with an industrial port area may make the project pay by proper planning of the upland and by provision for proper connection with the same.

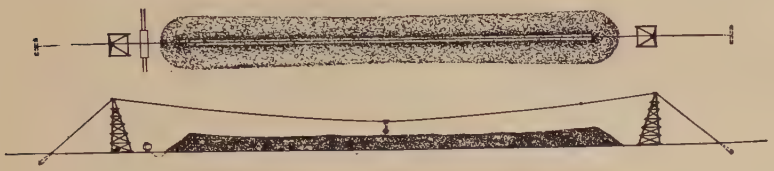
Fig. 267.

Fig. 268.

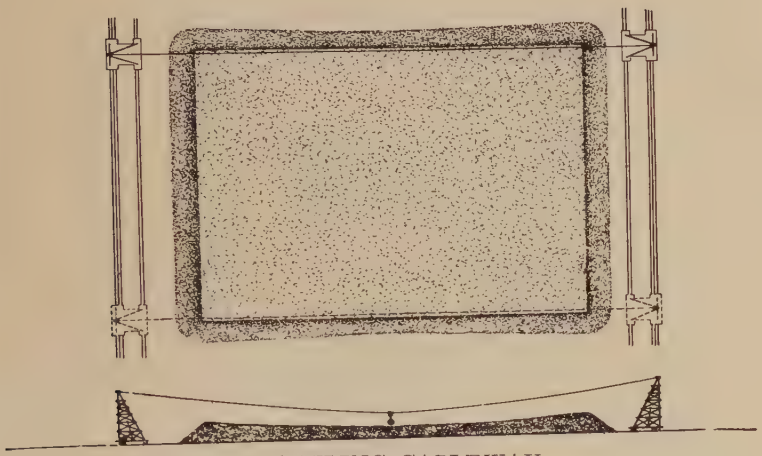
(Courtesy of C. of E., U. S. A.)

Figs. 267, 268.—Waterside location of large brick yards along the rivers and canals leading to Berlin has made possible a very economical delivery of the product. Containers (Fig. 267) the property of the Ziegeltransport A. G. Berlin or a similar contractor, are loaded at the brickyard onto barges, moved to the canal harbor nearest destination, where a crane transfers the container to horse or motor truck. The harbor (Fig. 268) is only two blocks from Potsdamer Platz, the traffic and business center of the city.

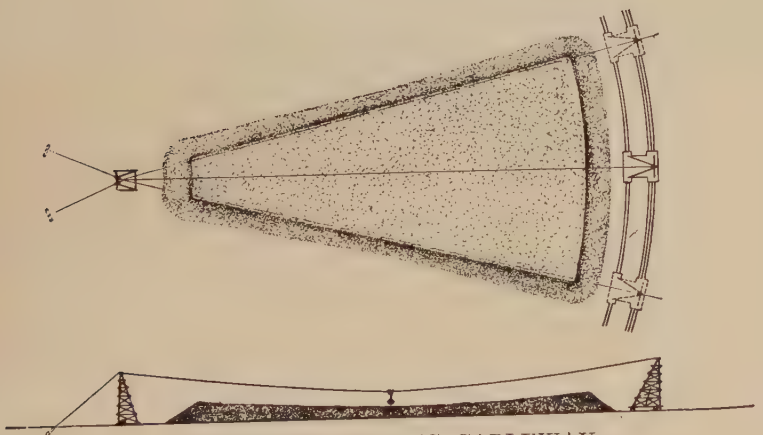
Three foreign layouts of upland connection are shown in Figs. 261, 262, 263, 264, 265, 266, 267, 268.



STATIONARY CABLEWAY



TRAVELING CABLEWAY



RADIAL TRAVELING CABLEWAY

TRANSFER

(*Courtesy of Lidgerwood.*)

FIG. 269.—Types of cableways.

CABLEWAYS

In further discussion of the connection of the waterfront with the upland industrial area the cableway may be examined more closely as a useful light-duty rig of considerable flexibility under many unusual conditions.

A cableway consists of a wire cable or a pair of them supported by two towers over which a carriage travels with a bucket or sling suspended on a winding mechanism and drawn by a towing cable. Cableways may be: (1) stationary, *i.e.*, fixed towers; (2) traveling, *i.e.*, both towers moved

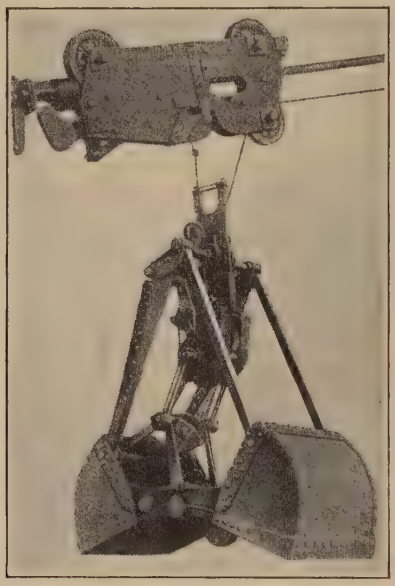


FIG. 270.—Bucket and traveling carriage of a "Blaw" automatic single rope cableway.

laterally on crane rails; (3) radial traveling, *i.e.*, one fixed tower and one traveling tower on a track that is the arc of a circle of which the cable is the radius (Figs. 269 and 270).

Varied Uses.—The many varied uses to which a cableway may be put in connecting vessels and upland are suggested by a few actual installations.

1. *For Riverside Construction Work.*—A Lidgerwood cableway was used at the foot of West Seventy-ninth Street, New York City, for unloading earth, which was conveyed about 500 feet, up steep banks and over the tracks of the New York Central and Hudson River Railroad. The cableway was adopted in place of teams on account of the heavy grade and to be out of the way of the railway traffic. The overhanging tower at the river terminus enabled the bucket to be dropped directly onto the scow. The plant unloaded daily a scow of 400 cubic yards, with

1-cubic yard buckets, load 1½ tons, and was operated by a 9- by 10-inch double cylinder, double drum Lidgerwood engine.

2. *For Lightering* (Fig. 271).—A long-span Lidgerwood cableway, 1,400 feet, is used to discharge practically all the freight received at Nome, Alaska, from lighters over the surf to wharves on the beach. The seacoast is open without harbor facilities, and vessels lying several miles off shore discharge their cargo onto lighters, which are brought under the cable for unloading. The tail tower, 80 feet high, is located on a concrete pier far enough out on the beach, which slopes very gradually, to be beyond the dangerous surf. This concrete pier is designed to withstand the ice pressure during the severe Arctic winter, and also forms an adequate anchorage for the cable, which is 2½ inches in diameter. The engine has double 12- by 12-inch cylinders and double 51-inch diameter drums, handling loads up to 8 to 10 tons at a very high speed.

(*Courtesy of Lidgerwood Mfg. Co., New York.*) (*John J. Sesnon.*)

FIG. 271.—Landing ship's cargo, Nome, Alaska, with an offshore cableway from a fixed head tower beyond the surf. Span, 1,400 feet; load, 4 to 8 tons.

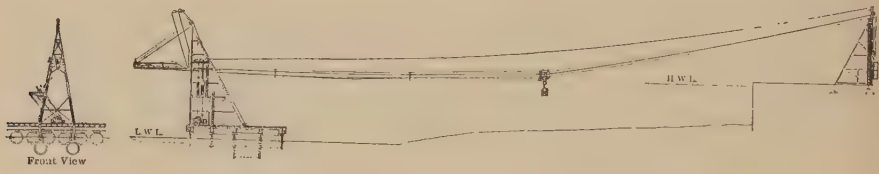
In front of the shore tower extensive storage for coal is provided under the cableway, without interfering with the dock space required for handling regular cargo.

3. *Floating Stage and Cableway at Manáos, Brazil* (Fig. 272).—Three electrically operated cableways for handling miscellaneous cargo from vessels, together with the complete power plant installation were furnished to Messrs. Booth and Company, London and New York, for the Manáos Harbor Works, Limited, Manáos, Brazil. This corporation virtually controls the traffic on the Amazon River, Manáos being located about 1,000 miles from the coast, the principal material handled being rubber. Cargo-carrying vessels, going up or down the Amazon River, deliver merchandise at this port, which has very extensive warehouses.

Owing to the extreme variation in the stage of the water between the wet and dry seasons, something over 50 feet, it was necessary to adopt some method for discharging cargoes at any stage of the water, and

inasmuch as the depth of the water at the outer end of the pier would be as much as 150 feet at high water, and with a soft treacherous river bottom, it was practically impossible to build a permanent dock or wharf. For this reason a steel pontoon plan was determined upon by Mr. Lavendeyra, engineer of the enterprise. This pontoon is anchored at a distance of about 326 feet from the shore or bulkhead line, the outer

FIG. 272A.—Head towers on a pontoon to overcome the great difference in water levels of the Amazon. Lidgerwood floating cableways of the Manáos Harbor Works, Ltd., Manáos, Brazil. Spans, 510 feet; load, 4 tons.



(*Courtesy of Lidgerwood Mfg. Co., New York.*)

FIG. 272B.—Diagram of cableways at Manáos, Brazil.

cableway towers being mounted thereon with overhanging booms reaching about 35 feet, and adapted to raise and lower to clear the ship's rigging. The inshore towers are permanently mounted on concrete foundations at the warehouses, the spans being 510 feet.

These cableways are adapted for handling loads of 4 tons, and are each capable of making from forty to fifty trips per hour.

The towers are built of steel. The head towers on the pontoon are 72 feet high, with 39-foot hinged booms, and the tail towers on the wharf are 51 feet high.

The main cables and operating ropes are all provided with counterweights which compensate for the variation in span, consequent to the rise and fall of the water, such counterweights automatically regulating the tension of main cable and operating ropes. The cableways operate continuously, regardless of the stage of water, and the tension devices maintain a constant stress in the lines, permitting the carriages to pass freely from the booms to the double cable trackway.

Each cableway is operated by special double 48-inch diameter friction-drum electric hoist, with 75 horsepower, 220-volt direct current motor, with a separate drum for raising and lowering the boom.

These cableway hoists are placed on the pontoon, each in the base of its tower, and the levers are carried to an elevated rack in the small house shown on the side of each tower, so that the engineman has a clear view of the cableway as well as the vessel's hatch.

The large steel pontoon, about 67 feet wide by 340 feet long, consists of many large, steel-riveted cylinders made watertight, and a heavy platform and framework of steel beams mounted thereon. This pontoon is held securely in position by heavy anchor chains, one at each corner; chains being tightened and adjusted by special compound geared hand winches, each chain running diagonally under the pontoon to very heavy cast-iron anchor weights. These chains are readily lengthened or shortened to accommodate varying stages of river level.

RECENT PROJECTS FOR INDUSTRIAL HARBORS

Newark Bay, Jamaica Bay, and Others.—There has been much agitation for industrial harbor improvement during the past few years. The areas where the projects are to be carried out are most promising of successful results as *industrial* ports. It is evident that in the minds of the general public and many officials there is no clear differentiation between the function and physical characteristics of the industrial and the commercial port.

The city of Newark has been working toward the development of the port of Newark. The government constructed a huge Army Supply Base during the War. Although progress has been made in developing freight liner services to the Pacific coast and some other points, Newark's future does not lie in the fact that there is berthing space for passenger liners at this port. There is an immeasurably rich future for Newark if it bends all its energies to building an industrial port where industries may have rail delivery to and from all the railroads, and above all easy lighterage and barge connection with the great commercial port of New York and its tremendous inland waterway system. The liner traffic wants to be as close to Fifth Avenue and Forty-second Street as possible. But if it is developed as an industrial port, lighters would put every factory in Newark Bay alongside every ocean ship in New York Bay.

Jamaica Bay is hardly more promising as a commercial seaport. Here, too, the real future lies in developing industrial areas with water and rail connection. It is most discouraging to find projects for Jamaica Bay improvements with the land all filled in to a regular straight bulkhead line, and plans for literally hundreds of long narrow piers like centipede legs extending at right angles into the fairway. It seems incredible that

anyone could dream of perpetuating the faults of New York's peculiar inherited conditions, that one should want to continue the congestion and inefficiency of the narrow uncorrelated piers which are New York's sorrow. There is such an expanse of possibilities at Jamaica Bay that the area should be reserved for the time when the port of New York can no longer accommodate overseas liner business. This area destined for a future commercial port should not be built upon now or otherwise improved haphazard as there may be many different needs to be met in the deep seaport of 25 or 50 years hence.

The larger part of Jamaica Bay is the hope of the future of manufacturing Greater New York. The effectiveness of the area in reducing the cost of transportation and therefore eventually the price of the products, not to mention the social benefits of garden cities like Port Sunlight in England, depends on the ability to move freight by water between Mill Basin and other developments and the city of liners in New York Bay. This can be done only when every factory site is assured of lighter connection at least. It is hardly possible to have all sites supplied with deep water to load ocean steamers. Yet all factory sites may be so laid out that every factory or loft building can have lighter connection with the whole of the water area of the port of New York. This is the great *raison d'être* of Jamaica Bay improvements and the possibilities are not understood, or for the sake of immediate profits are ignored. To be given an area of this size, quality, and dredging conditions, and then build it up solid with no water connection and with congested narrow piers is indeed like the Muckraker in "Pilgrim's Progress" who saw not the shining crown above his head.

The lighter is the greatest asset for inner harbor traffic in a port with the area of the New York and New Jersey waters. Not to plan to use it for every possible purpose, except railroad freight which should move by car, is indeed to fail to see the shining crown of unlimited economies and industrial growth. The Greater City must see the crown and plan for the future accordingly, at Jamaica Bay and elsewhere.

At present, under the existing rate structure, the outlying great projects are seriously handicapped because they are outside of the "free lighterage" limits. The same applies to Yonkers.

RECENT DEVELOPMENTS IN INDUSTRIAL HARBOR CONSTRUCTION

There have been several other extensive efforts during the past decade to extend the industrial areas served by navigable waters.

The Inner Harbor Navigation Canal at New Orleans (Fig. 273).—One of the most noteworthy examples of the extension of the industrial harbor is that of the Inner Harbor Navigation Canal at New Orleans, which was built by the Board of Commissioners of the port of New Orleans at

an expenditure of $20,000,000, and opened May 5, 1923. This canal connects the Mississippi River with Lake Pontchartrain.

The Board of Commissioners confidently expects that a great industrial city will develop on the banks of this canal. They expect to grow in port facilities on its banks measured only by the growth in wealth and commerce of the great Mississippi Valley which it serves. The main canal itself has dredged slips for the accommodation of ocean vessels, but laterals or side-arm canals, branching from the main canal, will give needed waterside connection to industrial plants.[1] To overcome

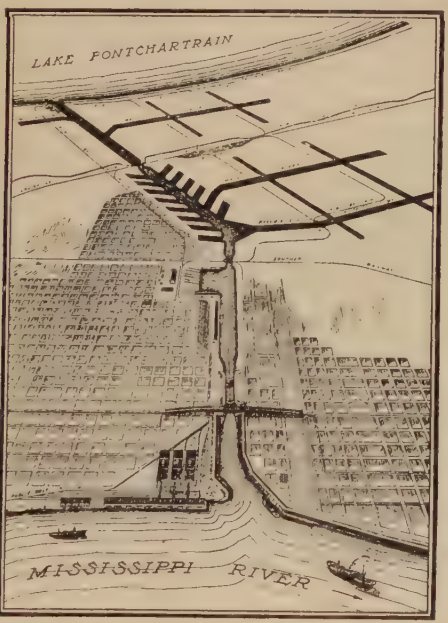


FIG. 273.—Industrial Canal, Port of New Orleans.

differences in water level, at the river end of the canal, is a lock 640 by 75 by 31½ feet over the sill at Mississippi River low water.

The Lake Washington Ship Canal at Seattle (Fig. 274).—A project quite similar to that of the New Orleans Industrial Canal is the Lake Washington Ship Canal, Seattle, Washington. This canal connects Puget Sound with Lake Union and Lake Washington in order to add a great industrial area to the shipping of Seattle's progressive harbor. Lake Union, the smaller of the two lakes, has an area of approximately 1,000 acres, over half of which is deep water. Lake Union is 25½ feet above extreme low tide in Puget Sound. Lake Washington is 19 miles long with an average width of 2 miles. The surface of this lake is 33 to 37 feet above low tide of Puget Sound. Both lakes are separated

[1] Advocated in the first edition of "Ports and Terminal Facilities in 1917."

from the Sound by high ridges, except certain narrow valleys which have been utilized in the construction of the canal. This canal is 8 miles in length between deep water in Puget Sound and Lake Washington. The channel is 150 feet wide at the bottom with a depth of 30 feet at low water. The works consist of locks and dam, the effect of which is to make of Lakes Union and Washington a huge wet dock with a great shore line upon which industries may be developed. Swamps along the shores of Lake Washington, aided by the lowering of the surface of the lake, have been converted into favorable sites for industries, adding industrial terrain eventually sufficient to offset the cost of construction of the canal. The large lock is 800 feet long, 80 feet wide, divided into two chambers 375 and 250 feet, by an underneath gate, and can accommodate vessels

(Courtesy of George F. Nicholson, sometime Chief Engineer, Port of Seattle.)

FIG. 274.—Lake Washington Ship Canal at Seattle to make available the shores of Lake Washington for industrial harbor development. Opened in 1917, the canal carried over two and a quarter million tons of shipping in 1923. Cost $6,000,000.

of the maximum draft of 36 feet. Alongside the south of the large lock is a much smaller one for vessels of the maximum draft of 16 feet. This lock is 30 by 150 feet. This may look like cutting a large hole for the cat and a smaller hole for the kitten; however, the object is to handle the great number of smaller draft vessels passing in and out without undue consumption of water in the lockages. In addition to the locks, there is a spillway 225 feet long with six spillway openings and a fishway which will permit salmon to pass into the locks. It is well known that the excessive construction of dams in New England waterways has almost entirely eliminated the salmon from that section of the country. It is to be noted with interest that provision for salmon runs have been made in this great project. During the first 6 years of operation the

traffic showed a large increase. The principal commodities were logs, lumber, and miscellaneous freight in barges.

1917	650,307 net registered tons of shipping
1921	1,513,353 net registered tons of shipping
1922	1,914,399 net registered tons of shipping
1923	2,266,394 net registered tons of shipping

Pacific Port Terminal, Oakland, Berkeley.—An unusual development of industrial harbor territory is that suggested by the late B. F. Cresson, Jr., and C. W. Saniford, Consulting Engineers for the city of Berkeley. The development is in fact a filled pier or tongue of reclaimed land approximately 2 miles long and more than ½ mile wide (3,000 feet), utilizing the shallow waters of the Oakland and Berkeley side of San Francisco Bay. It is possible to reclaim this land at the same time navigable channels of considerable width are created. The unit offers every element of a well-developed port. Deep waterfrontage with tracks, transit sheds, and warehouses flank the area while the great central portion is occupied by industrial sites and car-storage yards. There is provision made for vegetable oil storage in bulk, for passenger and team ferry slips. From the city planning standpoint there is a driveway along the outward end of the terrain, with a yacht basin, a monumental water gateway, and a certain number of residences for officials. I assume that motor buses or street cars will bring in the workers for the industrial plants and terminals. This idea of creating an ocean port terminal and industrial city, of several hundred acres, out of the bottom of the bay, is, without doubt, intriguing to the imagination, although real estate promoters are raising Venetian islands from the bottom of the sea at Miami. One thing is obviously lacking in this project, the lighter canal connection to warehouses on the artificial peninsula.

Lake Calumet Harbor.—Another industrial harbor development of first importance is that proposed for Lake Calumet Harbor, Chicago (Fig. 275). A number of engineers, including the late Colonel Jordan, had plans for this development. The entire project contemplates the utilization of Lake Calumet, near the boundary between Indiana and Illinois, a short distance from Lake Michigan, in the heart of the greatest concentration of large industries in the United States, if not in the world. The project will cover a total area of 2,104 acres of which 1,451 will be land and 693 acres water, offering a waterfront of 13.7 miles. The layout includes development of the channel of the Calumet River at one end and a new canal to the Calumet River at the other end, offering free circulation of water and traffic through the great basin. Through the usual methods of dredging and filling, there will be created altogether twelve basins 450 by 1,050 feet in the case of the smallest and 450 by 3,200 feet in the case of the largest basin, No. 9. The land areas vary in width from 900 feet for the smaller basins to 1,800 feet for the larger

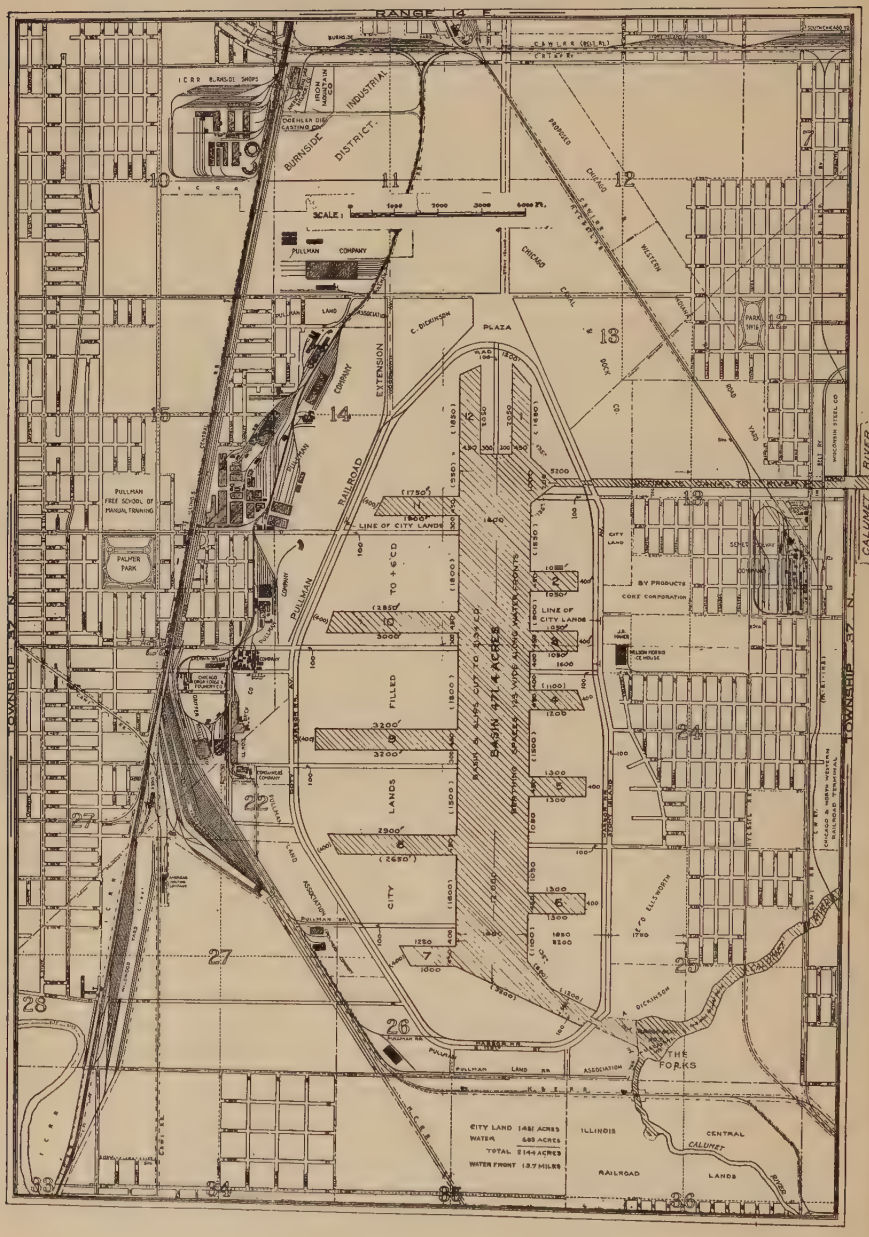


FIG. 275.—Plans for a huge industrial harbor. The Arend Van Vlissingen plan, Lake Calumet Harbor, Chicago.

basins. Berthing spaces 125 feet wide are reserved all along the waterfront, the remainder of the area between the basins being open to manufacturing plants and warehouses. The proportion between slip and land as well as the dimensions or width of the slips should be approximately correct, it being borne in mind that in all industrial harbor developments extensive bulkhead lines must serve as much of the industrial area as possible, and an overdevelopment of bulkhead compared with the factory sites will mean a capital expenditure per square foot of terrain that is uneconomical.

Industrial Areas at Hamburg.—At Hamburg, industrial areas served by various canals were quickly built up by industries and the canal net connecting the harbor with these industrial areas was being rapidly extended at the outbreak of the World War.

Trafford Park, Manchester.—A notable example of industrial harbor development is that of the Trafford Park estates at Manchester. Marshall Stevens, Member of Parliament, who was president of the Manchester Ship Canal Company for many years, was also a prime mover in the exploitation of the territory across from Manchester known as the Trafford Park Estates. This is a real estate venture on a large scale, dealing in Trafford Park with ship-side deliveries, set forth graphically bp the company's advertising manager.[1] Reduced to graphic form we have the arguments for the industrial harbor.

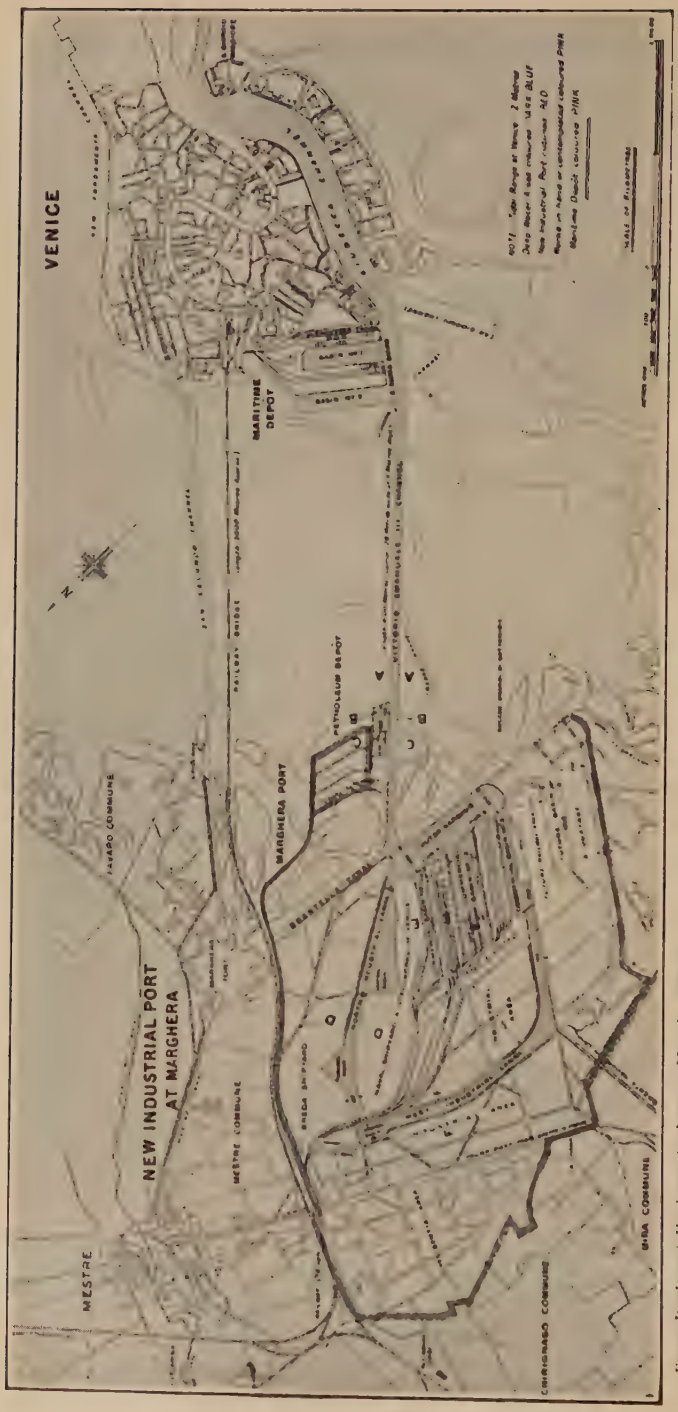
The New Industrial Harbor of Venice (Fig. 276).—As usual, this movement of industrial port development is not confined to the United States but finds many examples throughout the world. One of the most recent is that of Marghera near Venice. The industrial port of Marghera is connected with the Guidecca Channel by the Vittorio Emanuele III Channel, 4,100 meters long, 28 meters wide, and 9 meters deep. This port is situated on the mainland. It is also served by the Brenta navigation canal to the interior. It is obvious that Venice has no territory for industrial expansion. This movement for the construction of a large industrial harbor within close proximity to the ancient and picturesque city of canals, gondolas, and moonlight is a logical development to the growth and prosperity of the city.

It will therefore be seen that port cities are giving fully as much thought to the extension of their industrial harbors as to their transfer and warehousing facilities for deep-draft vessels.

Summary.—The economic principles upon which the industrial harbor is founded may be summarized as follows:

1. The evolution of world trade that makes all the world one market, makes it desirable for manufacturing plants to ship out their products to every corner of the world and therefore manufacture in such quantities that they can absorb shiploads of raw materials.

[1] See "Port Development," Chap. I (Fig. 1).



(*From Dock and Harbour Authority, March, 1924.*)

Fig. 276.—Venice and modern industrial efficiency. New industrial port at Marghera.

2. There is a great increase in the cost of handling freight, in spite of mechanical devices, due to the increase in wages (and in the size of ships), therefore transshipment is so expensive that it is to be avoided wherever possible. As a result every effort is made to bring the ship directly to the factory.

3. The realization on the part of the administrators of municipalities that payrolls are important to the prosperity of the city. By offering the advantages of inland and if possible deep-water transportation large industries will prefer the port city and will locate there.

4. The location at the port of industries that use offshore, intercoastal, or coastwise ships to assemble raw materials and distribute finished products is a great factor in port development as measured by entrances and clearances and in receipts for harbor and port facilities.

Conclusion.—With the necessity of high density compression to reduce the subject matter to the compass of one printed volumn many themes have of necessity only been touched upon and very few treated at all exhaustively. However, if some new angles of thought have been suggested and some new themes for more study presented, the author will feel that the decade of research embodied in these covers will have been in a good cause.

APPENDIX A[1]

BRITISH REGULATIONS AGAINST THE DISCHARGE OF OIL INTO NAVIGABLE WATERS[2]

Oil in Navigable Waters Act, 1922. Chap. 39.—An Act to make provision against the discharge or escape of oil into navigable waters. (Aug. 4, 1922.)

Be it enacted by the King's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:

I. Penalty for Discharge of Oil in Navigable Waters

1. If any oil is discharged, or allowed to escape, whether directly or indirectly, into any waters to which this Act applies from any vessel or from any place on land or from any apparatus used for the purpose of transferring oil from or to any vessel to or from any other vessel (whether a vessel to which this Act applies or not) or to or from any place, the owner or master of the vessel, from which the oil is discharged or allowed to escape, the occupier of the land, or the person having charge of the apparatus, as the case may be, shall be guilty of an offense and shall, in respect of each such offense, be liable on summary conviction to a fine not exceeding 100 pounds:

Provided that it shall be a good defense to proceedings for an offense under this section to prove:

a. If the proceedings are against the owner or master of a vessel, that the escape of the oil was due to, or that it was necessary to discharge the oil by reason of, the vessel being in collision or the happening to the vessel of some damage or accident, and also, if the proceedings are in respect of an escape of oil, that all reasonable means were taken by the master to prevent the escape; and

b. if the proceedings are against any other person and are in respect of an escape of oil, that all reasonable means were taken by that person to prevent the escape.

2. It shall be lawful for a harbor authority to appoint a place within his jurisdiction at which the ballast water of vessels in which a cargo of petroleum spirit has been carried may be discharged, and where a place is so appointed any such ballast water may, notwithstanding anything in this section, be discharged at that place, but only at such times and subject to such conditions as the harbor authority may from time to time determine:

Provided that the foregoing provision shall not apply to ballast water containing oil other than petroleum spirit.

For the purposes of this subsection, the expression "petroleum spirit" means refined petroleum which is subject to rapid evaporation and which, when tested in the manner prescribed by the Petroleum Act, 1879, or any enactment amending that Act, gives off an inflammable vapor at a temperature of less than 73 degrees Fahrenheit.

II. Prohibition of Transfer of Oil at Night

1. It shall not be lawful during the hours between sunset and sunrise to transfer any oil to or from any vessel lying in any harbor unless notice of intention so to do has been given in accordance with the provisions of this section.

[1] From *Marine Engineering and Shipping Age*, November, 1922.

[2] From the Transportation Division, Department of Commerce, Washington, D. C.

2. If any oil is transferred to or from any vessel in contravention of the provisions of this section, the master of the vessel and, if the oil is transferred from or to premises on land, the occupier of the premises shall, in respect of each offense, be liable on summary conviction to a fine not exceeding 20 pounds.

3. A notice for the purpose of this section must be given to the harbor master of the harbor in which the vessel is lying and shall be of no effect unless given at least 3 hours and not more than 96 hours before the time at which the operation of transferring the oil commences:

Provided that, in the case of an operation to be performed at a place where such operations are frequently and regularly carried on, or in the case of a transfer of oil for fire brigade purposes, the notice may, instead of being a notice given to the harbor master within the time hereinbefore provided, be a general notice given to the harbor master to the effect that such operations will, during such a period not exceeding 12 months from the date of notice, as may be specified therein, be carried on between sunset and sunrise.

III. Keeping of Records with Respect to Transfer of Oil

1. There shall be kept in the case of every vessel a record, in such form as the Board of Trade may prescribe, of all operations in connection with the transfer of oil to and from the vessel.

2. The record required to be kept under this section shall, in the case of a barge, be kept, so far as relates to the transfer of oil to the barge, by the person supplying the oil, and, so far as relates to the transfer of oil from the barge by the person to whom the oil is delivered, and shall, in every other case, be kept by the master of the vessel.

3. Every record kept under this section may at all reasonable times be inspected by the harbor master of the harbor in which the vessel is or, in the case of a barge, was at the time of transfer or by any person duly authorized in that behalf by the Board of Trade, the Minister of Agriculture and Fisheries, the Fishery Board for Scotland, or the Ministry of Commerce for Northern Ireland.

4. If any person required to keep a record under this section fails to keep such a record or to make proper entries therein, or to produce the record on a demand in that behalf made by any person authorized to inspect it, he shall, in respect of each offense, be liable on summary conviction to a fine not exceeding 50 pounds, and if any such person makes any entry in the record which is to his knowledge false or in any material particular misleading, or wilfully fails to make any entry in the record, he shall, in respect of each offense, be liable on summary conviction to a fine not exceeding 100 pounds.

IV. Liquid Contained in Spaces Used for Carriage

1. Where oil has been contained in any tanks or other spaces in a vessel, any liquid discharged or allowed to escape from those tanks or spaces shall, unless it is proved that the tanks or spaces have been cleaned of oil, or that the liquid has been freed from oil by means of a separating apparatus, be deemed to be oil within the meaning of this Act.

2. In the case of proceedings against any person other than the master of a vessel, evidence of the matters aforesaid may be given by means of a certificate signed by the master, and, if the master of a vessel gives any certificate under this section which is to his knowledge false or in any material particular misleading, he shall, on summary conviction, be liable in respect of each offense to a fine not exceeding 50 pounds.

3. In this section the expression "master of a vessel" means the person named as the master in the agreement with the crew.

V. Application of Fines

Where any person is convicted of the offense of having in contravention of the provisions of this Act discharged or allowed to escape any oil into any waters to which this Act applies, the court before which he is convicted may, on application of the prosecutor, order that the whole or any part of the fine imposed in respect of the offense shall be paid to such person as the court may direct for the purpose of being applied by him in or towards meeting any expenses incurred or to be incurred in the removal of the oil so discharged or allowed to escape.

VI. Power to Inspect Premises and Vessels

1. The Board of Trade may, if they think fit, either at their own instance or at the instance of the Minister of Agriculture and Fisheries, the Fishery Board for Scotland, or the Ministry of Commerce for Northern Ireland, or of any local authority, appoint any officer of the Board of Trade or any other competent and independent person to inspect any vessel being in any waters to which this Act applies, and any person so appointed or the harbor master of the harbor in which the vessel is may at all reasonable times enter upon the vessel and examine the measures adopted to prevent the escape of oil.

2. If it is represented to the Board of Trade, by the Minister of Agriculture and Fisheries, the Fishery Board of Scotland, or the Ministry of Commerce for Northern Ireland, or by any local or harbor authority, that there is reason to suspect that oil is escaping or has escaped, whether directly or indirectly, into waters to which this Act applies from premises adjacent to or in the neighborhood of those waters, the Board of Trade may, if they think fit, appoint any officer of the Board or other competent and independent person to inspect the premises, and any officer or person so appointed may at all reasonable times enter upon and inspect the premises.

3. If any person obstructs or interferes with any person authorized to enter on any premises or vessels under this section, he shall, on summary conviction, be liable in respect of each offense to a fine not exceeding 10 pounds.

VII. Legal Proceedings

1. Where an offense under this Act is alleged to have been committed by the master of a vessel who thereafter departs from Great Britain and Northern Ireland before the expiration of the period within which proceedings for the offense might have been instituted against him, proceedings for the offense may, notwithstanding any thing in the Summary Jurisdiction Acts, be instituted against him at any time within 2 months next after the date on which he first returns to Great Britain or Northern Ireland.

2. For the purpose of any proceedings for an offense under this Act, the offense may be treated as having been committed either at the place at which it was actually committed or at any place in which the person charged with the offense may at any time be.

3. Where a fine imposed by any court in proceedings against the owner or master of a vessel for an offense under this Act is not paid at the time and in manner ordered by the court, the court shall, without prejudice to any other powers of the court for enforcing payment, have power to direct the amount remaining unpaid to be levied by distress or poinding and sale of the vessel, her tackle, furniture, and apparel.

4. Proceedings for an offense under this Act shall not be instituted in the case of an offense committed in or in relation to the waters of a harbor except by the harbor authority, and in any other case except by a person authorized in that behalf by special or general directions of the Board of Trade, the Minister of Agriculture and Fisheries,

or the Ministry of Commerce for Northern Ireland: Provided that nothing in this subsection shall apply to the institution of proceedings in Scotland.

VIII. Interpretation and Application

1. In this Act, unless the context otherwise requires:

The expression "oil" means oil of any description, and includes spirit produced from oil and oil mixed with water.

The expression "harbor" means any harbor whether natural or artificial, and includes any port, dock, estuary or arm of the sea, any river or canal navigable by sea-going vessels, and any waters in which sea-going vessels can obtain shelter or ship or unship goods or passengers.

The expression "harbor authority" includes all persons or bodies of persons, corporate or unincorporate, being proprietors of or entrusted with the duty or invested with the power of constructing, improving, managing, regulating or maintaining a harbor.

The expression "harbor master" includes any person appointed by a harbor authority for the purpose of enforcing the provisions of this Act.

The expression "master" when used in relation to any vessel means the person having the command or charge of the vessel for the time being.

The expression "vessel" has the same meaning as in the Merchant Shipping Act, 1894:

The expression "barge" includes lighter or like vessel.

The expression "transfer" in relation to oil means transfer in bulk.

The expression "local authority" means, in the application of this Act to England, the council of a county or county borough or urban or rural district or a port sanitary authority, in the application of this Act to Scotland the council of a county or burgh or a port local authority, and, in the application of this Act to Northern Ireland, the council of a county, county borough or county district, or a port sanitary authority.

2. This Act shall apply to any vessel which is capable of carrying in bulk, whether for cargo or for bunker purposes, more than 25 tons of oil, or which, though not so capable is constructed or fitted to carry in bulk as aforesaid more than 5 tons of oil in any one space or container.

3. The waters to which this Act applies are the territorial waters of Great Britain and Northern Ireland and the waters of harbors therein.

4. For the purposes of section six of the Government of Ireland Act, 1920, this Act in its application to Northern Ireland shall be deemed to be an Act passed before the appointed day.

IX. Short Title and Saving

1. This Act may be cited as the Oil in Navigable Waters Act, 1922.

2. The provisions of this Act shall be in addition to, and not in derogation of, or substitution for, any provisions for the protection of a harbor as defined in this Act contained in any existing Act or reenactment thereof or in any such Act or any reenactment thereof.

3. This Act shall come into operation on the first day of January, 1923.

APPENDIX B

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